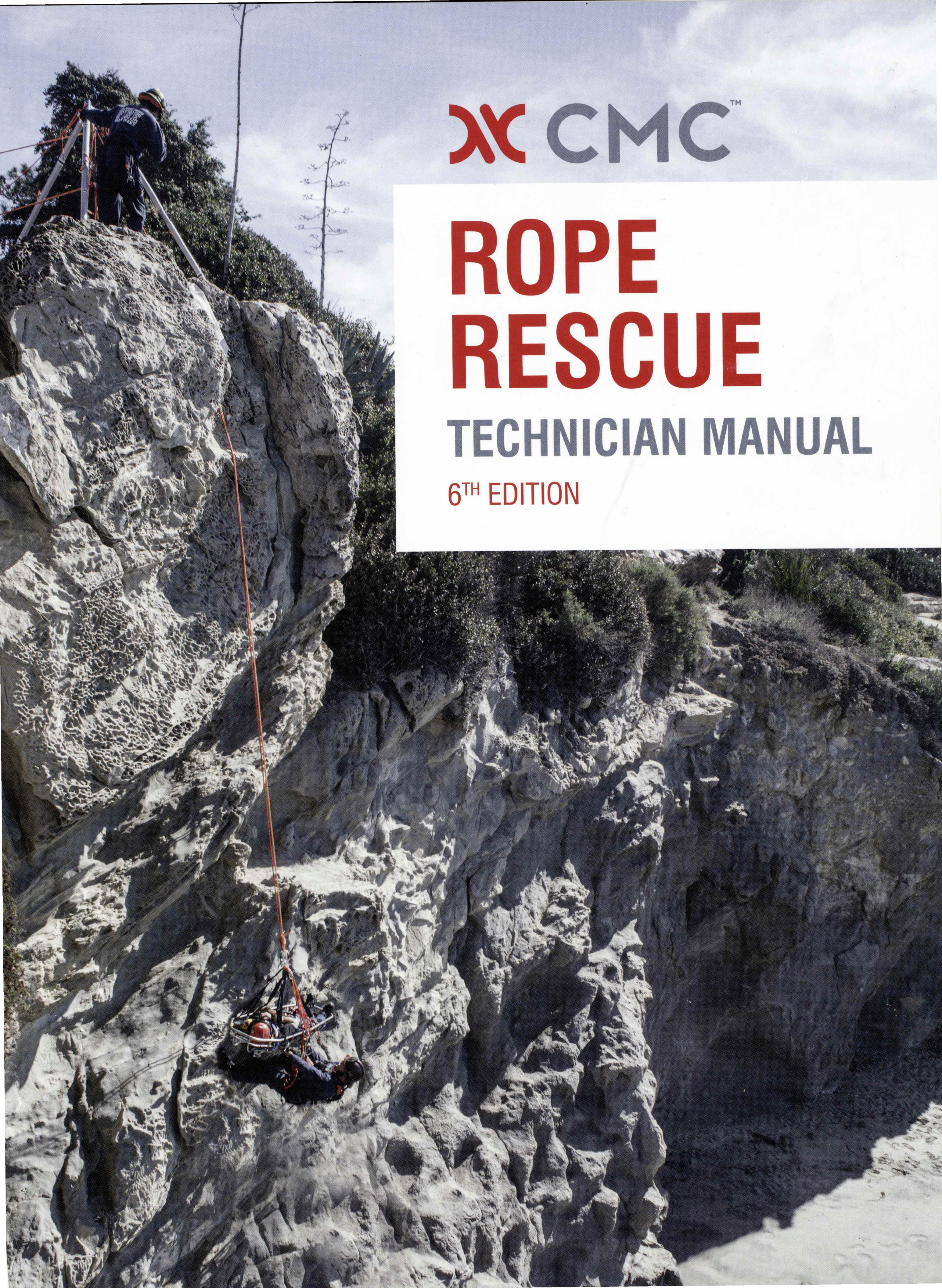

CMC™

ROPE RESCUE

TECHNICIAN MANUAL

6TH EDITION

CMC™

ROPE RESCUE

TECHNICIAN MANUAL

6TH EDITION

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CONTENTS

Part 01 **Getting Started** 1

Chapter 01 Learning Rope Rescue 1

Chapter 02 Safety 7

Chapter 03 Standards and Regulations 15

Chapter 04 Life Safety Equipment Testing 23

Part 02 **Rope Rescue Equipment** 27

Chapter 05 Life Safety Rope & Webbing 27

Chapter 06 Rope Rescue Hardware 41

Chapter 07 Personal Equipment 71

Part 03 **Basic Skills** 81

Chapter 08 Knots 81

Chapter 09 Anchors 99

Chapter 10 Anchor Systems 113

Chapter 11 Edge Protection 119

Chapter 12 Patient Packaging 125

Chapter 13 Litters & Litter Rigging 133

Part 04 **Rescue Systems** 141

Chapter 14 Twin-Tension Systems 141

Chapter 15 Belay Systems 149

Chapter 16 Lowering Systems 157

Chapter 17 Raising Systems & Mechanical Advantage 167

Chapter 18 Reversing a System 183

Chapter 19 Knot Pass Through a System 189

Chapter 20 Analyzing a Rope Rescue System 199

Part 05 **Individual Skills** 217

Chapter 21 Rappelling 217

Chapter 22 Ascending 237

Chapter 23 Fall Protection 245

Part 06 **Rescue Techniques** **253**
Chapter 24 Access & Stabilization 253
Chapter 25 Stranded Person Pick-Off 259
Chapter 26 High Angle Litter Evacuations 267
Chapter 27 Low Angle Litter Evacuations 277
Chapter 28 Guiding Lines 283
Chapter 29 High Lines 291
Chapter 30 High Anchors & Directionals 299
Chapter 31 Ladder Rescue Systems 311
Part 07 **Rescues** **319**
Chapter 32 Organization & Planning 319
Chapter 33 Putting It All Together 325
Part 08 **Special Applications** **331**
Chapter 34 Rope Access 331
Chapter 35 Antenna, Tower & Caged Ladder Rescue 359
Chapter 36 Escape & Bailout 363
Chapter 37 Snow & Smooth Slope Evacuations 373

IMPORTANT WARNING

Technical rescue, work at height, and related training are hazardous activities. Effective risk management comes from experience, training, and the exercise of good personal judgment. It is your responsibility to obtain competent instruction, choose quality equipment and use adequate safety procedures.

The publisher has made its best effort to provide the reader with the most current information reflecting the state of the art in rope rescue at the time of publication. It is incumbent on the reader to:

- Determine if the skills and techniques provided are compatible with the reader's systems, techniques, protocols, equipment and level of training.
- Recognize that rope rescue is an evolving discipline and to stay current with new information, improvements in equipment, advances in techniques and changes in standards.

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The *CMC Rope Rescue Technician Manual* is intended as an aid to training, not a substitute for it. Because the authors and publisher have no control over the level of training you will receive or the amount of experience you will gain, neither the authors nor CMC Rescue, Inc., a California corporation, its officers, directors or shareholders are responsible for the reader's use of this book or any information contained within.

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"An unplanned rescue will probably be your last."

—CMC Confined Space Rescue Technician Manual

WHAT'S NEW IN THE SIXTH EDITION

In the Sixth Edition of the CMC Rope Rescue Technician Manual we have split the Litter Operations chapter into High Angle and Low Angle chapters. Twin Tension Systems is now a stand-alone chapter and we have added a chapter on Ladder Rescue Systems. NFPA 1006 references have been added to each chapter where they apply. The rope access chapter has been updated to the latest terminology and rigging.

New products include:

- CMC G11 Lifeline, a NFPA G-rated 11 mm life safety rope
- CMC CLUTCH™ by Harken Industrial
- LEVR™ Escape System
- AZORP (Omni Directional Rigging Pod)
- Hurley Picket Anchor System

INTRODUCTION

The CMC School has been teaching rope rescue classes to emergency responders since 1982. Our full-time and part-time instructors all have emergency service backgrounds: professional, volunteer, and now a few retired. Our training curriculum is a combination of their real-life experience and the knowledge gained in CMC's over 40 years as a designer, manufacturer, and distributor of rescue equipment. CMC instructors are active in the rope rescue community and teach courses worldwide. New techniques are evaluated and refined in our classes and our test facility.

This background has allowed the development of concepts and techniques that have withstood critical analysis and that have been proven in the field. We urge you to carefully consider what we suggest and honestly think about the advantages and disadvantages in terms of the rescues your organization conducts. Our purpose in writing this manual is not to change what you are doing but to provide insights, alternatives and options to continually improve your organization's capabilities.

The CMC Rope Rescue Technician Manual is intended to support hands-on training from qualified instructors who are experienced in teaching rope rescue skills. While the manual provides a source for the technical knowledge and skill involved in rope rescue, regular practice of personal and team skills is essential in order to be a safe and effective rescuer.

Whether you are taking a CMC class or any one of the other leading rope rescue classes, the CMC Rope Rescue Technician Manual provides an excellent resource for developing your knowledge and skills.

EDITORIAL NOTES

Brand names of products have been used for descriptive purposes and are not endorsements of those products unless stated. The purchasing of personal use or team equipment calls for learning how to use it. Ask questions of knowledgeable people, refer to national or state standards, and look to see what rescue instructors and experienced responders are using.

It has been pointed out to us that the ***CMC Rope Rescue Technician Manual*** frequently mentions CMC products. Our mission as a company is to provide rescuers with the best products possible. We use those products in our classes and as examples in our manuals. Many CMC products were developed to meet specialized needs and in those cases we often recommend the CMC product. We recognize that other manufacturers offer many excellent products and many of them are also in the manual as well as our school equipment caches. Trade names of products are used for clarity or because a generic name does not exist.

In most cases we use the term ***subject*** instead of ***victim*** as a matter of preference. When we discuss medical care, we use the term ***patient***.

We considered converting all measurements to SI units. Some standards are now in SI units and some are still in US units. However, things like the term ***1-inch tubular web*** is not likely to become ***25 mm web***. Therefore, like our rescue industry, the manual is a mix of both SI and US units.

ACKNOWLEDGMENTS

We want to thank the many people that have contributed to the manual over six editions. This group includes CMC's office staff, engineers, and instructors as well as our students, vendors and customers. In particular, we would like to thank the following CMC instructors and other staff for their contributions:

Bruce Parker – CMC Rescue, Inc. (retired)

Fred Salazar – Colorado Springs (CO) Fire Department

Jim Bolton – Reno (NV) Fire Department

Dan "Kaz" Kazmierski – Milwaukee (WI) Fire Department (retired)

Mike Teff – Madison (WI) Fire Department (retired)

Matt Scharper – California State SAR Coordinator - Cal OES Law Enforcement (retired)

Shaun Reed – Mechanical Engineer

Our association with other rescuers through Santa Barbara County Search and Rescue, the Montrose Search and Rescue Team, the Mountain Rescue Association, the National Park Service, the National Association for Search and Rescue and the Society of Professional Rope Access Technicians has provided a wealth of feedback to help direct our efforts through the years. Our participation on NFPA, ASSE and ASTM standards committees has also contributed to our background of knowledge.

PART 01

Getting Started

CHAPTER 01

Learning Rope Rescue

TERMINAL LEARNING OBJECTIVE

This chapter serves as the introduction to the manual and provides the student with an overview of considerations for learning rope rescue.

ENABLING LEARNING OBJECTIVES

1. Evaluation of potential instructors
2. Describe the value of standardized systems
3. Describe the value of a team manual

When reading this chapter, consider how it relates to your rope rescue technician training and to your team as you learn to perform rope rescue operations. Most of the suggestions are valuable for both the individual and the team.

Selecting a Rope Rescue School or Instructor

There are many ways to learn more about rope rescue. The best is to put your team through a rescue class taught on the type of terrain similar to where you perform your rescues. An instructor from outside your team can bring in new information and variations in techniques. They can look at your team's operations from a fresh vantage point and may see things your in-house instructors overlook.

The considerations for selecting an instructor for your team or a rope rescue school to attend are very similar. Since a nationally recognized certification for rope rescue instructors does not exist, anyone can present themselves as an instructor. If someone will pay for their services, they become a "professional" instructor. We have seen classes offered by instructors whose only qualification was that they had taken an introductory rope rescue class. This puts the responsibility on your organization or on yourself to do the investigation. Ask questions about:

- Course content and scope
- Source of any certification
- Previous classes
- Instructor's teaching experience
- Instructor's rescue experience
- Liability insurance

Look at the course content and its goals. If they claim that they can take a beginner and certify them as a rope rescue technician or rescue instructor in four hours, or even in a full weekend, you should be suspicious. A good course will spend time teaching the fundamentals. Before they offer you an advanced course, they should want to know how much experience and training you have already had.

What is your goal in taking the class? Is it compliance motivated with a certificate as the primary goal? Or are you after the knowledge and skill development that will make you a better rescuer? The quality of the instructors, the depth of the curriculum, the amount of hands-on practice and the opportunity to apply the skills in rescue scenarios are what develops your capabilities as a rescuer.

Ask about references. Find out who has taken the course and what they thought of it. Make sure the student really feels they developed skills in the class rather than was just dazzled by the volume of material or by the excitement of their first rappel. Find out if the instructor has the teaching ability to effectively communicate the material. Ask:

- How many students will be in the class?
- What is the student/instructor ratio?

- Is it taught in the classroom or the field?
- What is the ratio between hands-on practice and classroom work?
- Is the class taught on your own terrain?
- What is their safety record?

Next, find out the name of the instructors teaching the class. Look at their qualifications:

- Do the instructors have an emergency services background?
- How much experience do the instructors have as teachers?
- Are the instructors full-time, part-time or occasional?
- Can they supply references from past classes?
- Have the instructors been involved in actual rope rescues?

We think the last point—Have the instructors been involved in actual rope rescues?—is very important. An instructor with actual rescue experience brings an important connection to the real world that is missing with an instructor whose background is only attending rescue courses.

Today there are a lot more people teaching rope rescue than a few years ago. By talking to students who have taken other courses we have found that courses usually reflect the instructor's own training and experience. Nobody can honestly claim to teach you everything that you need to know, although some courses are much more thorough than others. Attending one training course does not mean that your rescue education is anywhere near complete. You will not know how much you did not learn until you take a better course or work with more highly trained personnel.

Getting the Most Out of a Class

Here are some tips to help you get the most out of your time (and money) spent at a rope rescue training. First, check your physical condition. Rappel towers and hillsides for practice rescues will require multiple trips back to the top. On your first rappel, you may find yourself gripping the rope with enough intensity to strain muscles and ligaments. Stretch your legs and ankles, so they will have the flexibility for the extra bending they will receive. Rappelling and rescue systems are heavy physical work, so make sure you are up to lifting litters and hauling on ropes.

When in the class, you need to strike a balance between asking questions and letting the instructor teach the class. Usually there is at least one student who has a desire to show what they know rather than to learn what is being taught. A good instructor will try to work in alternate ideas, but their primary responsibility is to the entire class, making sure they learn what they came to class to learn.

Hands-on practice makes the theory and the skills come together and reinforces the learning. What you hear in class is not retained as much as what you do in class. This is also your opportunity to work through the systems under the experienced eye of your instructor.

Other Sources for Learning

Books and magazines are great for review and for looking at different ideas and concepts. Some of them have been around a long time, but there is something to learn in all of them. Rescue seminars are also a good place to learn as they give you a chance to talk to other rescue people and see demonstrations of how other teams approach their technical problems.

Standardizing Systems

Standardizing your team's rescue systems reduces the amount of knowledge that the student must learn to be able to perform well as part of the team. The standardized systems approach avoids the problem of being introduced to a wide range of skills and then trying to fit them together as a functioning system in the middle of a rescue. Instead, the team can review and train for what works best for most of their responses, and both old and new team members will know what to expect. With a knowledge of the team's basic rescue skills, the new person can participate in rescues and begin to develop field experience. With the building blocks of basic skills and field experience, the team member can go on to learn advanced skills and develop leadership capabilities. Such an approach has been in use in the fire service and emergency medicine for many years.

Team Manual

A team manual of standard operating procedures or guidelines serves several functions. Primarily, it is a resource that helps team members learn and review the team's systems. The manual illustrates team procedures to the new member, allows self study work by the novice and resolves confusion about what are the systems the team prefers.

Writing a team manual requires the team to thoroughly study what it is doing. Putting it down on paper causes you to look at things from a different viewpoint, which may help you catch mistakes or highlight places where finesse may be added. This is the time to review your procedures and set your standards or guidelines.

Instead of trying to rewrite the rope rescue textbooks, you can incorporate by reference the parts that your team has adopted as standard procedures. Your manual will have more credibility if it refers to published rescue texts rather than using a cut, paste and copy approach. Of course this will require a team library, but you should have one anyway.

Equally important, the team manual documents team training and response standards should they ever be called into question by another agency or a court of law. It is much better to turn to a document and show a standard for performance that you meet than to rely on a variety of opinions regarding your team's skill levels and adequacy of training.

Improvisation

While the ability to improvise is important, it is sometimes used as an excuse for not learning the fundamental skills. Being able to adapt your skills to fit the unexpected requires that you have already learned those skills. Standardizing your team's fundamental skills makes learning easier. It also provides the ability to perform on the more routine responses where you develop the experience and judgment necessary for effectiveness and safety.

Reviewing

If your team cannot honestly analyze its performance after a training or rescue, then it cannot improve. Complimenting your team on a job well done is fine, but it is the search for improvement that makes your team better. It is the responsibility of your team leaders to set up the review process and to use it.

Every rescue could have been done a little safer or a little quicker. Even the ones that seem textbook perfect could have had a little more finesse. It is also important to point out what worked exceptionally well in order to reinforce training. A team member's improvised solution may provide a better way of handling a particular situation or suggest a change in procedures.

Training scenarios and rescues should be debriefed from start to finish. Look for ways to save time, eliminate confusion or increase safety. Review team procedures and standards and adjust as necessary. Any problem, especially an accident or near accident, should be discussed in an objective manner. The best rescue teams are the ones that have the courage and the willingness to critique their performance.

Notes

PART
01
Getting Started

CHAPTER
02
Safety

TERMINAL LEARNING OBJECTIVE

The student will be able to understand the principles of safety during rope rescue operations.

ENABLING LEARNING OBJECTIVES

1. Perform a risk analysis of a rope rescue system
2. Describe when to use belays vs. single rope techniques
3. Describe the concept of redundancy
4. Perform a safety check of a rope rescue system

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.1.3 | 5.2.7

A rescue that requires ropes and rope systems will always have an element of risk, but they may be the safest way or the only way to resolve the problem. The goal is to remove the subject as quickly as possible from their predicament while minimizing the risk to the rescuers and subject. With proper training, effective communications and good safety habits the risks can be greatly reduced.

Risk Analysis

Understanding the exposures to risk will let you determine how to best minimize them. This is as true for rope rescue as any other form of rescue and for many of the risk sport recreational activities. Look at your procedures and try to determine the areas of weakness. Things that can hurt you include:

- **System failure** – are the anchors and the components strong enough?
- **Human failure** – is training appropriate and are skills current?
- **Communication failure** – is there a plan and are team members talking?

Rope rescue combines technical knowledge with judgment in many of the steps along the way. This begins with the decision for the organization to develop a rope rescue capability and continues with the training of personnel. Some organizations do not respond to rope rescue incidents on a frequent basis, and like all perishable skills, regular training is required to keep both the individuals and the team at a safe level of competency.

Decisions made regarding the types of systems and equipment that will be used will have an impact on the safety of a rescue. Will you belay all rope rescue systems or just high angle ones? Will single rope technique be safer than using a belay line? Will you use two tenders on a high angle rescue or just one? Is your belay system mechanically strong but dependent on a highly skilled operator? Can you save weight by selecting equipment that is adequately strong? These are just some of the questions that should be considered when developing the program.

National Fire Protection Association (NFPA) 1670 *Standard on Operations and Training for Technical Search and Rescue Incidents* provides a guide for organizations intending to provide rescue services to their community. The chapters on each rescue discipline list the capabilities an organization should have to perform a rescue at the operational or technician level. While all of the items in the rope rescue chapter may not apply to your organization and area of responsibility, it provides a good starting point.

System Strength

The strength of a rope rescue system is essentially the strength of the weakest link in the system. The strength of each component in the system is determined by the tensile strength when new, less what age and use have done to weaken it, plus the effects caused by its placement in the system.

A good example is the rescue rope. We know a rope loses strength from age and use. When placed in a system, it usually has a knot involved with a corresponding significant strength reduction. Understanding the physics of your system as it is used is essential to a safe rescue, and in Chapter 20 we will look at margins of safety, system safety factors and system analysis in much more depth.

Redundancy

The rope rescue skills that we teach are based on systems that are backed up by another system. We call this a double-rope (or two-rope) system. Each anchor point is backed up by another, and each primary rope is belayed by another. If the primary system should fail, the belay will hold you. Ask yourself, "If this part of the system or this connection point in the system fails, what will catch me?"

There are limitations on how far you can carry this approach. You can get so carried away with a backup for everything that your system becomes so cumbersome or takes so long to rig that it is no longer functional. Keeping your litter tender hanging in the harness while the system is over-engineered for the raising may increase the risk of harm to the rescuer as well as delay the rescue of the patient. There may also be environmental reasons for maximizing efficiency, such as wet or cold weather that make patient care more involved.

You need to balance the likelihood of failure, the possible ways to minimize failure and your options to provide for a backup. Sometimes backing up a part of the system may not be possible. If you decide to proceed without a backup, then you must be aware that there is a critical weak link in your safety chain.

Belays

If the failure of the primary support system for the rescuer, subject or both has the potential for injury, a belay system should be used. During a rescue, a failure could occur due to difficult terrain, lack of adequate anchors or a mistake due to difficult conditions. Be sure to consider the entire evacuation route—it may be easy terrain to start with but have a vertical section part of the way.

It is critical that the belay can support the full weight of the system, plus the added dynamic force of a main line failure. With Twin-Tension Systems, each side must have the capability of supporting the load by itself.

Protecting students during classes and training is equally important. Accidents can result while learning new skills, and stepping over the edge for the first time can be a significant distraction.

Single-Rope Technique (SRT)

This is an exception to always using a belay on a rescue system. Sometimes two ropes can cause problems that offset the advantage of a safety belay. When rappelling and ascending long drops, cavers discovered that the belay line would twist around the main line, often stopping movement. To address this problem, cavers developed single-rope techniques. They chose to reduce their redundancy by eliminating the belay line in exchange for a functional system.

Safety with SRT requires you to be better at analyzing what you are doing and more meticulous when doing it. You will want the highest-quality rope since it is your sole means of support. When you rig your anchor, realize that there will not be a belay system to back it up. Place edge protection and make sure your rope stays on it.

When working on a single line, we use a rule of two points of contact to the rope at all times. This allows one point of contact to fail without dropping you. Essentially you are belaying yourself and attaching that belay to the same rope that you are hanging on. If a point of contact needs to be removed, such as when changing from a descender to an ascender, a third point of contact is added first.

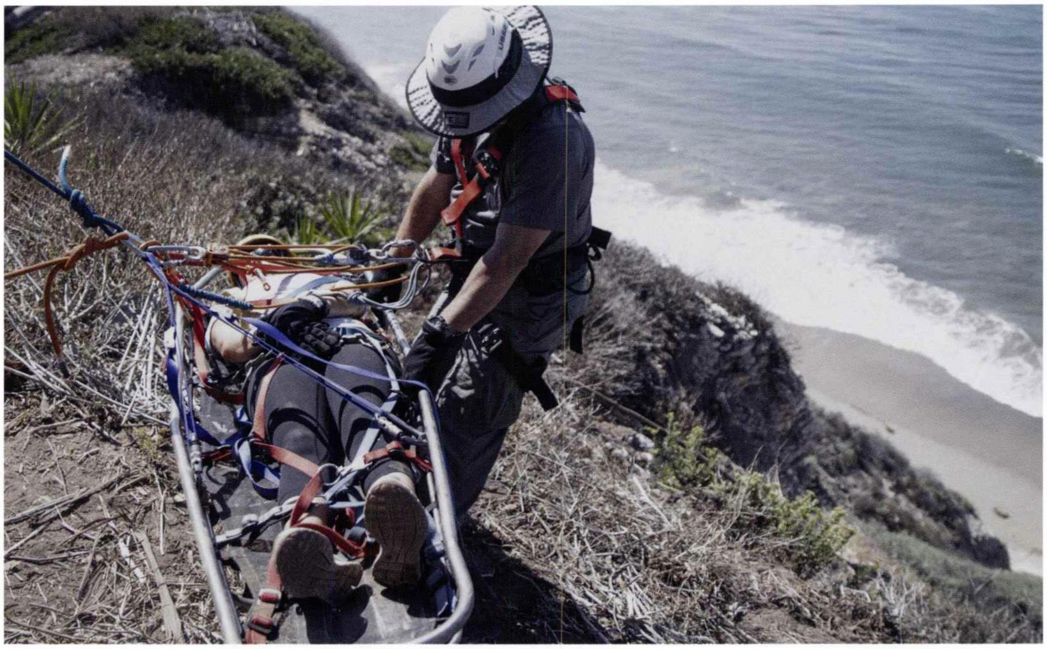
Check and Double Check

The amount of time it takes to do a safety check of your system is so small and so valuable to your safety that there is no excuse for not doing it. Remember to check what others set up for you as well as your own work. Standardized equipment and procedures greatly speed up the safety checks because everyone knows what to expect and where to expect it. Use both of the following two systems for checking to help identify mistakes.

Safety Check – Whether working in pairs or with a separate safety officer, someone checks your rigging. A different set of eyes may catch something that yours have missed. Check the system after it is rigged; check it again any time the system is modified.

Touch System – It is easy to think through a checking procedure yet not see what you are looking at, thereby missing a step. Pilots use the touch system when checking their instruments and the same concept will work for you. When you check your set-up, touch each of the parts to make sure you really see it. If you cannot reach it, at least point to it.

Repetitive evolutions during training exercises require repetitive safety checks. Rigging suitable for a rescue may begin to show significant wear during repeated evolutions. Check before each.



SAFETY DURING TRAINING

Fear

We have worked with several people that were genuinely terrified of trusting their life to a "thin" rope. Fear can cause mistakes, and in one case the suspected cause of a rappel accident was a blackout due to fear. Early in a team member's training is the time to identify and address any issues with the exposure to height.

Fear, a normal response to height, is overcome by confidence in your equipment and skills. Management of fear requires shifting your focus from the height above the ground to the fundamentals of rope work. Focus on the task at hand: rigging the equipment, the safety check and proper rappel technique.

Selection of personnel for a high angle rescue team should take into consideration a person's ability to work at height. Some people can learn to deal with height and some cannot. The latter can be effective team members for low angle rope rescue responses or in a support role as long as they are not put in an exposed position.

The first involvement with fear is usually when teaching a new team member to rappel. If you start them at a lower height with the rope coming from above, they will be able to put their weight on the rope and develop a higher level of trust before making a difficult start or beginning with a high rappel. In the CMC Basic Rappelling for the Emergency Responder Class, we start the students on a stairway. This eliminates the sensation of height and students are able to focus on technique. When they have mastered the use of the equipment, we move to a cliff side.

Having team members proficient in managing the belay line is a very important element in the safety of your system. Using a belay when teaching rappelling makes the learning safer but also provides training and practice in belay skills.

Live Load Versus a Simulated Load

There is a difference of opinion on whether a rescue manikin should be used rather than a live person for rope rescue training. Some departments have a policy that prohibits using a live person for training. They feel that there is no justification for putting someone at risk when a rescue manikin can provide the same function.

Many rescue instructors feel that the experience of being in the patient's position during a training scenario is very informative and the value gained is well worth the minimal risk. Seeing the rescue from the patient's perspective also allows an analysis of how smoothly, comfortably and efficiently the evolution is conducted. This feedback will help improve overall team competence.

Another consideration is placing the patient into position to start a scenario. If the training includes loading the patient on difficult terrain, then a live patient provides a more realistic situation, particularly with the conscious patient who can assist the rescuer. It may also be safer to place a live patient into the location rather than trying to manipulate a heavy manikin into place.

The deciding factor is the perception of the risk. If it is that dangerous to be in the litter, then it is probably equally dangerous to be tending that litter. At this point, additional training may be required before the team puts anyone on rope.

Multi-Agency Responses

Working alone, your team has control over the techniques, equipment and tactics it will use. Yet in many jurisdictions, the rope rescue team will be involved with a first responder medical unit, a police or fire unit or another rescue squad. If you already have a good working relationship with the agency you are supporting, many of the following problems will have been solved. However, if the agencies are new to each other, it will take time to recognize each other's capabilities and to develop a level of confidence. Team leader meetings and joint trainings will help.

Your Team's Safety – No matter who is in charge of the incident, your team leader is still responsible for the safety of your team. If your team leader does not have enough control over your team's part in the incident to insure an acceptable level of safety, they may have to decline to participate. It is a tough choice to refuse to assist in an emergency, but none of your team members have signed on to take unwarranted risks.

This judgment call can only be backed up with a sound knowledge of the fundamentals of rescue and the experience to recognize quickly when another agency exceeds the limits of reasonable prudence. This is a time for firmness and tact in communications, and not the time for debating rescue techniques. A decision not to participate will cause trouble. Afterward you will have to explain your decision and justify your standards of safety.

Sizing Up the Situation – When you arrive on the scene, your team leader should first find out who is in charge of the incident and talk to this person to determine how your unit fits into the incident plan, then receive a thorough briefing on the situation and your team's responsibilities. Find out the command system and note who you will report to and where the people in charge will be. Also determine who has the medical responsibility if your team will be working around the patient. If your team's medics have higher qualifications, notify the person in command and offer their assistance.

As far as it affects your team's participation, find out what has been done, what needs doing and the nature of any anticipated problems. Then look around to see if what you have been told fits what you see. Here again, the experience of your team leaders will allow you to understand quickly the essentials of your part in the incident and not waste time picking over irrelevant details. The same procedure applies when one of your field teams arrives on location. Find out who's in charge, get a briefing and get to work.

Stabilize and Belay – If you're working with an agency with little experience in rope rescue, your initial concern will be to stabilize the subject and establish belays for every person exposed to falling. If ropes have already been rigged, check them quickly. Make sure that the subject, whether they are in a litter or not, has a belay. When you have confirmed that everything and everyone is stable, which should only take a few minutes, you can start your evacuation plan.

On a low angle rescue, if a belay is not in place, your first rescuers down to the scene should bring it with them. Not only is it useful as a hand line or rappel line on the way down, but the belay for the patient can be established as soon as you arrive. While one team member works with the ropes and checks the subject's physical stability, your medical person can talk to the medical officer in charge of the subject to review patient care and packaging. When the channels of communication are opened by intelligent questions and you have proven yourselves with practical suggestions, then the organization of the litter team will follow automatically.

The same thing should be happening on top. Interface with the team leader. Learn what has already been done, check the anchors and look at the systems. Time will be saved if you can build upon the work already done. Get the teams working together, no matter who is in charge.

Not every agency will have the same expertise in rope rescue. Your team can be a valuable asset if it quickly merges into an ongoing response in an intelligent and professional manner. It helps a lot if you have worked with the other agencies in the past. If you have not, then at the scene you will have to establish not only your expertise in rope rescue, but your ability to communicate and work with others.

PART 01

Getting Started

CHAPTER 03

Standards and Regulations

TERMINAL LEARNING OBJECTIVE

The student will identify the regulations and standards that pertain to rope rescue equipment and operations.

ENABLING LEARNING OBJECTIVES

1. Identify the agencies and organizations that create standards and regulations for rope rescue
2. Describe the significant standards that govern rope rescue equipment and training

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.2.3

One of the significant areas of development in rope rescue over the last few years has been in the area of standards and regulations. Some are training guidelines or professional qualifications for the individual, others apply to the organizations providing rope rescue services, and some are for the manufacturers of rescue equipment and clothing.

While learning to understand standards lacks the excitement of rappelling down a cliff or setting up a rope rescue system, there are several important reasons you should know them.

- The standard may have a legal backing with penalties that could affect your organization or yourself. State and federal regulations definitely fit into the must-do category.
- The person quoting the standard may be getting it wrong or misapplying the standard to the situation.
- The standard may be used to determine the standard of care or duty to others in a negligence-based lawsuit.

Standards are written by a committee under the authority of an organization in the standards writing business. The committees are typically composed of members of the related community who were willing to volunteer their time to make sure that when a standard is written, it is as good as it can be. Even if you are not on a committee, you can still participate by working on one of the task groups or by providing public comment.

Consensus standards then go out to a larger group, often the full community itself for review prior to publication. The schedule for the development of the standard and the period for public comment can be found on the organization's website. Standards writing organizations, such as NFPA, ASTM and ASSP, provide the administrative structure that ensures that the standard is fairly written and all comments are addressed. Most standards are on a review cycle and are revised or confirmed by the committee on a set schedule.

Government regulations are very different from standards although they often relate to each other. Regulations are created by lawmakers and government officials, and failing to adhere to them can result in fines or other penalties. Often the regulation will refer to an existing standard or actually adopt a standard, making it a regulation.

Organizations, such as NFPA, ASTM, and ASSP, for example, are in the standards writing business. Their revenue derives from the sale of the standards that they produce. It should not be surprising then that their standards are protected by copyrights. The committees for these three organizations are made up of subject matter experts drawn from users, manufacturers, certification organizations and government. Committee members, such as CMC's staff, donate their time to ensure quality standards are developed and up to date with industry practices.

The following sections include a brief overview of the primary standards that touch on rope rescue operations. The website contact information for the organizations that develop and administer the standard is included, so you can look up a standard, know when a standard is open for public comment or consider joining a committee.

Occupational Safety and Health Administration (OSHA)

OSHA is a federal agency concerned with the safety of the worker. OSHA ensures that regulations are written to protect employees. States may write their own safety regulations as long as they provide an equal or greater level of protection to the employee. Check to see if your state is a federal plan or a state plan state.

Although OSHA often says that it does not regulate rescue and many public safety organizations often feel similarly, this may not be the case. For example, the regulation for confined space rescue was written specifically because nearly 60% of the fatalities in a confined space incident were rescuers. Three OSHA regulations that do apply to rescue are:

CFR 1926 Subpart M – Fall Protection

Section 1926.502(d) (20) states that "the employer shall provide for prompt rescue of employees in the event of a fall..."

CFR 1910.146 Permit – Required Confined Spaces

Section (k), titled Rescue and Emergency Services, lists specific requirements for rescuers responding to a confined space incident.

CFR 1926.650 Subpart P, Excavations

The federal standard for trenching and excavation operations, including rescue.

Contact: osha.gov

ASTM International

Formerly the American Society of Testing and Materials, ASTM International develops a very wide range of industry standards. Committee F32 on Search and Rescue has developed more than 40 standards relating to search and rescue. Recently the National Association for Search and Rescue (NASAR) has requested Committee F32 to assume the management of NASAR's search and rescue standards. A few particularly applicable to rope rescue are:

F1740 Standard Guide for Inspection of Nylon, Polyester, Nylon/Polyester Blend, or Both Kernmantle Rope

A long title, but the standard is referenced by most of the rope manufacturers and many training organizations as the standard on rescue rope inspection and retirement.

F1768 Standard Guide for Using Whistle Signals During Rope Rescue Operations

Radios can fail at the most annoying time or due to environmental conditions, such as caves or waterfalls, preventing effective communication.

F2436 Standard Test Method for Measuring the Performance of Synthetic Rope Rescue Belay Systems Using a Drop Test

This is a test method that allows the user to compare the performance of one belay system with another even when the tests are done by different groups.

F2266 Standard Specification for Masses Used in Testing Rescue Systems and Components

For comparison testing, standardization is needed. F2266 suggests several standard masses for the five primary rescue loads a system is likely to see.

F2684 Standard Test Method for Portable High Anchor Devices

Provides a standardized test method for comparing the performance of tripods and other high anchor devices.

F2491 Standard Guide for Determining Safety Factors for Technical Rescue Systems and Equipment

This guide covers the general concepts for calculating load ratios for rope rescue systems.

F2821 Standard Test Methods for Basket Type Rescue Litters

Provides the basic test method for certifying rescue litters for both horizontal and vertical evacuations.

F2822 Standard Specification for Fixed Anchorages Installed on Structures used for Rope Rescue Training

Provides guidance when constructing training towers or adding fixed anchorages to current towers.

Contact: astm.org

Cordage Institute

The Cordage Institute has a technical committee that is involved in the development of standards and guidelines using the voluntary consensus process. The institute publishes a technical manual and documents on the safe use of cordage and rope.

CI International Standard 1800: Test Method for Life Safety Rope and Accessory Cords for Life Safety Applications

This is a manufacturer's standard that includes the test method for the kernmantle construction rope used in rescue. It is referenced by *NFPA 1983: Standard on Life Safety Rope and Equipment for Emergency Services*

CI International Standard 1801: Performance Requirements for Low Stretch and Static Life Safety Rope

Identifies the general characteristics of low stretch and static kernmantle rope used for life safety applications.

CI International Standard 1803: Kernmantle Accessory Cords for Life Safety Applications

The manufacturer's standard covering the characteristics of kernmantle accessory cords used for life safety applications. "Cord" is defined as a material with a diameter from 4 to 8 mm (0.16 to 0.31 in)

CI International Guideline 2001: Fiber Rope Inspection and Retirement Criteria

A small booklet with guidelines for inspecting and retiring ropes of several different constructions and types of fibers.

CI International Guideline 2005: Inspection of Kernmantle Ropes for Life Safety Applications

The Cordage Institute's guideline for the inspection of life safety kernmantle ropes.

Contact: ropecord.com

National Fire Protection Association (NFPA)

NFPA International produces a wide range of standards from the National Electrical Code to fire sprinkler codes and many standards relating directly to rope rescue. Each standard is administered by a committee and each standard is open for public comment.

NFPA 1983: Standard on Life Safety Rope and Equipment for Emergency Services*

NFPA 1983 is a standard for manufacturers that details the design specifications, performance, labeling and testing of life safety rope, harnesses and hardware. It specifically excludes rope and equipment for mountain rescue, cave rescue, lead climbing and "where expected hazards and situations dictate other performance requirements." An example of "other performance requirements" might be a dielectric rope used for certain tower rescues.

NFPA 1983 groups equipment into three designations of performance based on the design load of the certified rope and equipment. ***General use*** is defined as equipment "designed for general-use loads, technical-use loads and escape." ***Technical use (formerly light use)*** is for equipment "designed for technical-use loads and escape." ***Escape*** is for equipment designed for firefighter emergency egress. As you can see, the higher performance standard includes the lesser performance standards.

There are several misconceptions about 1983 that have persisted long enough that we cover them here:

> NFPA 1983 is not a ***use*** document. It does not tell a department or firefighter which equipment should be used for a rescue operation. That information can be found in NFPA 1500 and 1858.
>
> NFPA 1983 does not say you have to use a two-person rope. Besides not being a use document, the two-person and one-person terms have not appeared in any of the recent editions of the standard.
>
> NFPA 1983 does not require departments to use steel carabiners. We hear this frequently and the word ***steel*** in that context does not appear in the document. Again, it is not a use document.

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* As of March 2020, NFPA plans to combine standards 1670, 1983, and 1858 in to a new standard, NFPA 2500. This new standard is in a custom cycle and is scheduled for release in 2022.

NFPA 1983 does not require a 8,992 lbf (40 kN) rating on all equipment. This is the performance requirement for general-use life safety rope. Other rope and most of the equipment have their own specific strength requirements.

NFPA 1983 does not require a 15:1 margin of safety. Again, not a use standard. This misconception came from the early calculation used to determine what performance specification the committee wanted for a general-use life safety rope. Starting with a design load of 600 lbf, the committee picked a multiple of 15 to get a 8,992 lbf requirement.

A manufacturer cannot self-certify that a product meets NFPA 1983. The standard requires an independent certification organization whose label must be on the product. Going even further, the standard specifically says that the NFPA name may not be used with any product that does not comply with the standard, which includes full certification.

In the 2017 edition of 1983, the documents was reorganized for much easier to use by matching up the requirements in the sections on Labeling and Information, Design and Construction Requirements, and Performance Requirements.

NFPA 1858: Standard on Selection, Care, and Maintenance of Life Safety Rope and Equipment for Emergency Services*

This is the user document that compliments NFPA 1983. While the document is fairly brief, the authors put a lot of work into the Appendix to provide the user with the understanding of life safety rope and equipment's manufacture, use, care and maintenance.

NFPA 1500: Standard on Fire Department Occupational Safety, Health, and Wellness Program

Section 7.19 *Life Safety Rope and System Components* references NFPA 1983 and provides use criteria for firefighting, rescue and other emergency operations, including training. NFPA 1500 also details training, education and practice requirements that a department should provide for its personnel.

NFPA 1006: Standard for Technical Rescue Personnel Professional Qualifications

NFPA 1006 provides the minimum job performance requirements for Awareness, Operations and Technician level rescuer. The 20 disciplines include one on Rope Rescue. Joint meetings of the committees continue to work on aligning personnel requirements with organization requirements.

NFPA 1670: Standard on Operations and Training for Technical Search and Rescue Incidents*

NFPA 1670 is a use document for organizations planning to provide technical rescue services to their community. It provides a guideline as to what capabilities the AHJ (authority having jurisdiction) should expect from the organization. NFPA 1670 is separated into a general requirement chapter and then additional chapters for the 19 specific rescue disciplines.

* As of March 2020, NFPA plans to combine standards 1670, 1983, and 1858 in to a new standard, NFPA 2500. This new standard is in a custom cycle and is scheduled for release in 2022.

NFPA 1670 appears very general in its content since it was written to identify capabilities but not to tell the AHJ or the organization how they must do a rescue. The committee recognized that the particular requirements to conduct rescue incidents vary widely throughout the country and even locally. The organization would be expected to handle the type of incidents in their response area.

Like NFPA 1983, there is some confusion over the application of NFPA 1670 when it comes to individual training. A rescue training program could cover the skills that meet the guidelines in NFPA 1670; an individual cannot be certified as meeting that standard since it was written to define the capability requirements of the organization.

Contact: nfpa.org

American Society of Safety Professionals (ASSP)

ANSI/ASSP Z359 Fall Protection Code

ASSP is the secretariat for the ANSI Z359 ***Fall Protection Code***. This is a major revision of ANSI Z359.1, which was the safety requirements for fall protection equipment. The code is a series of standards relating to safety for employees working at height.

Contact: assp.org

American National Standards Institute (ANSI)

ANSI oversees and accredits other organizations that develop standards. It assures that the secretariat for the standard has followed a process that allows for public input and comment on the standards. ANSI approval of a proposed standard helps assure only one standard on a particular subject. Examples are ANSI/ASSE Z359 and ANSI/NFPA 1983.

Contact: ansi.org

International Technical Rescue Association (ITRA)

International Technical Rescue Association (ITRA) is a non-profit organization that provides world-wide recognition of technical rescue practitioners and instructors in rescue disciplines including swiftwater, rope, boat, confined space, structural collapse (USAR), and animal rescue. Its goal is to promote global safe practices and standards for rescue response and training. ITRA provides assessment of rescue instructors providing external validation for both in-house and commercial instructors.

Contact: itra.international

European Standards

With the importation of European recreational climbing, industrial rope access and rescue equipment, the CE mark or UIAA certification may be seen.

Comité Européen de Normalisation (CEN)

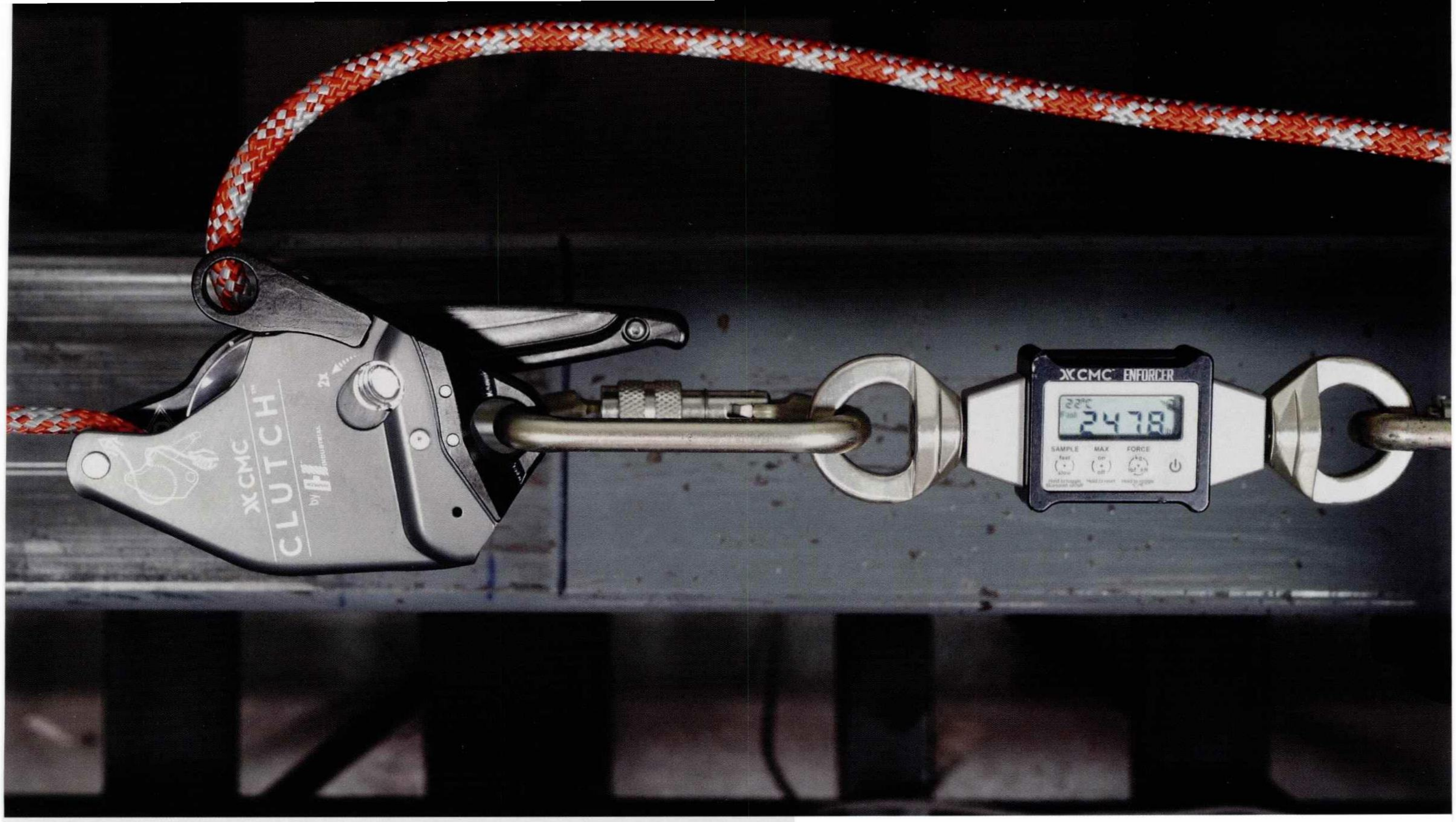
This organization sets European equipment standards for many industries. The Personal Protective Equipment Regulation requires certain equipment to be CEN approved and stamped with the CE mark, particularly concerning work at height. The other commonly seen CE mark is for recreational climbing equipment.

Union of International Alpine Associations (UIAA) European

Administers sport climbing and mountaineering equipment standards. Compliance is voluntary. The UIAA standards are being phased into the CEN.

CONCLUSION

Standards and regulations affect the planning and the conduct for a rescue response. Some standards are guidelines that have national consensus and some are regulations that have the force of law. Both affect how others will view your performance, either when determining your readiness or when evaluating the rescue afterward.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PART 01

Getting Started

CHAPTER 04

Life Safety Equipment Testing

TERMINAL LEARNING OBJECTIVE

The student will be able to describe the performance limitations of rope rescue equipment based upon how that equipment is tested and certified.

ENABLING LEARNING OBJECTIVES

1. Define the key elements of NFPA 1983
2. Explain the "three sigma" reporting standard

NSTRON
5584

3 Sigma (3σ) Calculation

If you tested five samples of lifeline and obtained the following results:

Test #1	**9,870 lbf**	**(44.24 kN)**
Test #2	**9,940 lbf**	**(44.55 kN)**
Test #3	**9,890 lbf**	**(44.33 kN)**
Test #4	**10,010 lbf**	**(44.87 kN)**
Test #5	**9,790 lbf**	**(43.88 kN)**
Mean	**9,900 lbf**	**(44.37 kN)**
σ	**82 lbf**	**(0.36 kN)**

Then the standard deviation (σ) is determined using the following formula, where n is the number of test samples and x is the test result for each sample.

$$\sigma = \sqrt{\frac{n(\Sigma x^2) - (\Sigma x)^2}{n(n-1)}}$$

The new rope 3σ minimum breaking strength (MBS) would be determined by subtracting three standard deviations from the mean result of the five samples.

Chapter 3 was about standards, this one is about how products are tested to those standards. The performance requirements in the standards try to match how a product is used in the field with how it can be tested in the laboratory with consistency and repeatability. While it is not practical to test, say a carabiner in every manner it might be connected into a system, the performance requirements do their best to cover the most likely loadings in the field.

What comes as a surprise to some is the amount of variation between test samples. Even a product as simple as an Anchor Plate subjected to the same test method on the same test equipment, will have a different result for each sample. Some results can be very close, such as metal products, and some results can vary widely, such as assembled systems.

Different standards use different approaches to end up with that one number that is marked on the product. ANSI Z359 tests five samples of carabiners and all five must exceed the minimum requirement. For example, 5,000 lbf for the major axis. The carabiner is then marked with a load rating of 5,000 lbf and that it is ANSI Z359.12 compliant.

The test methods in NFPA 1983 require 5 samples tested to failure and then use a statistical formula to determine the result. Called 3-sigma, the calculation takes three standard deviations from the mean result to determine the test strength of the product. The result is that there is a 99.87% predictability that the carabiner you have in your hand is the same or greater than that result.

If the 3 sigma result exceeds the minimum performance, then the product passes that performance requirement. NFPA allows the manufacturer then to mark the product with either the minimum performance requirement or the 3-sigma value. Most manufacturers do the latter, usually rounding down, to allow for variations when the product goes in for recertification.

For litters and tripods, NFPA uses a minimum breaking strength test method. Two samples are tested, and the lowest result of the two is used to determine passing. Again, the manufacturer can choose to mark the product with the performance requirement or the minimum result.

Not all products have a performance requirement that requires testing to failure, such as harnesses and belay devices. This is why a harness does not have a strength rating.

Testing a descent control device or a rope grab to failure does not provide usable information. What we want to know is how strong the device is when connected to the rope and at what point the device begins to damage the rope. In most cases, it is the rope that fails rather than the device itself. With descent control devices, most are intended to slip when loaded beyond a certain point, so they have to be tied-off in some manner to be able to apply sufficient load to create a failure.

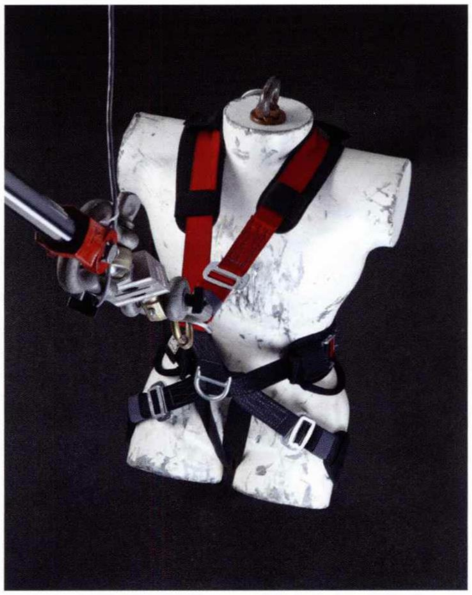
NFPA TEST METHODS

The following is an overview of some of the test methods for products certified to NFPA 1983, the primary standard in use for rope rescue equipment. For specifics, please refer to current edition of NFPA 1983 *Standard on Life Safety Rope and Equipment for Emergency Services.*

Life Safety Rope

NFPA 1983 refers to the Cordage Institute Standard CI 1800 *Test Method for Life Safety Rope and Accessory Cords for Life Safety Applications* procedure for the rope test. Besides the actual tensile strength of the product, what is of interest is the elongation. To meet the requirement for a low stretch or static rope, the elongation at 10% of the breaking strength must be between 1% and 10%. Added in a recent edition of the standard was the requirement to report the elongation at 1.35 kN (300 lbf), 2.7 kN (600 lbf) and 4.4 kN (1,000 lbf), numbers that are useful for field use.

Harnesses and Belts

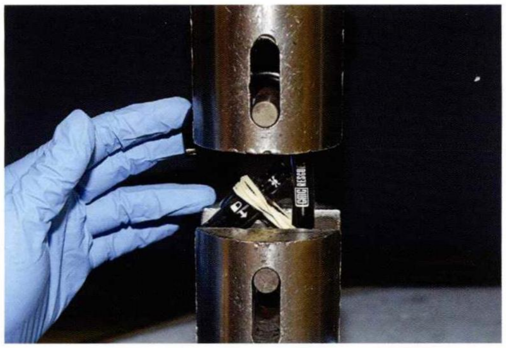


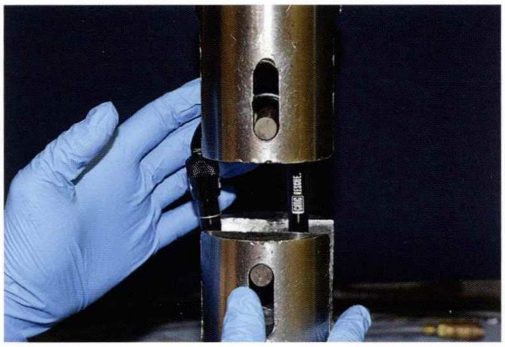
A harness or a belt is subjected to a static test and a dynamic test. For the dynamic test, each harness and escape belt is dropped twice, once in a head up position and then in a head down position. The drop is one meter relative to the attachment point using a steel cable, a severe drop with no energy absorption such as from rope stretch in a typical system.

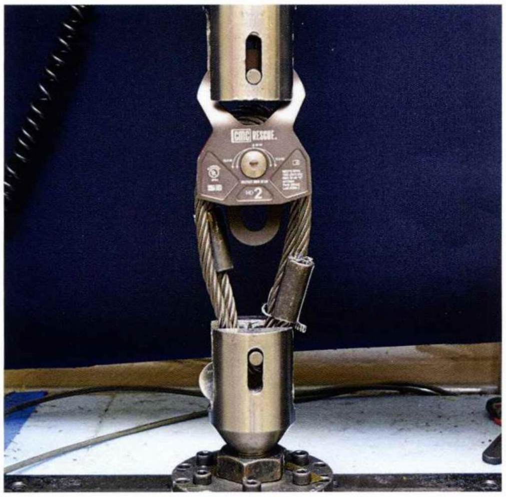
For the static test, each sample is connected at each attachment point and subjected to a prescribed force for a specified number of minutes. The test load varies depending on whether the attachment point is load-bearing or a positioning attachment point. Points designed to be used as pairs, such as shoulder or hip D-Rings, are tested as pairs.

Extrication Devices

Extrication devices are treated just like a harness with the head up for the Class II and both head up and down tests for the Class III.







Carabiners

Because carabiners can move about in a rope system such they that they might be loaded other than on the major axis, the NFPA test method includes both a major axis and minor axis as well as a gate open test.

Pulleys

A steel cable around the sheave is used to determine the strength of a pulley to eliminate the variability that would be added by using different brands and types of rope. A test for pulley efficiency has been discussed for years, but a reliable and repeatable test method has yet to be proposed.

Belay Devices

ASTM F2436 *Standard Test Method for Measuring the Performance of Synthetic Rope Rescue Belay Systems Using a Drop Test* as modified by NFPA 1983 is used to test belay devices. A test mass, 136 kg (300 lb) for Technical use and 280 kg (617 lb) for General use, is dropped 60 cm (23 in) on 3 m (9.8 ft) of life safety rope. The resulting impact force must be less than 15 kN (3,372 lbf) and the device must release the test mass in a controlled manner. The maximum extension of the belay system shall be no more than 1 meter (3.28 ft).

Manner of Function Tests

This test applies to ascenders, rope grabs, descent control devices and belay devices. The test evaluates the performance of the device when connected to the rope. Does the device hold under a normal load with a sufficient margin of safety when overloaded?

To determine the pass/fail load for devices such as those used for descent control that are designed to slip at a certain load if auto-locking, or like the Figure 8 Descender and Brake Bar Rack not auto-locking, the device must be tied off for the tensile test.

This was a quick overview of just some of the test methods in the standard. For a complete understanding, you should read the standard itself.

*Industry specifications for stainless steel and aluminum have a lot of variability. Products made in one year may be interestingly different from a production run five years later.

**CMC thanks Andrew White, Tommy Mangum, and Beverly Stutts from UL for the hardware testing photos in this chapter.

PART 02

Rope Rescue Equipment

CHAPTER 05

Life Safety Rope & Webbing

TERMINAL LEARNING OBJECTIVE

The student will be able to describe the construction, materials, and uses of rope rescue software.

ENABLING LEARNING OBJECTIVES

1. Describe the characteristics of life safety rope
2. Describe the use and care of life safety rope and webbing
3. Describe how to clean, store and retire life safety rope and webbing

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.2.3 | 5.2.7

Man has been using rope for movement in the vertical environment since prehistoric times. Early ropes were manufactured out of cotton, rawhide, hemp, agave or whatever fibrous material was available. A by-product of World War II was the development of synthetic fibers, a significant improvement since natural-fiber rope begins to degrade as soon as the plant is harvested.

Continued development of rope for rescue applications came from recreational climbing and caving. Early ropes were stretchy climbing ropes and very stiff caving ropes. Over the past 30 years, the rescue rope product has been greatly refined by various manufacturers offering a variety of fibers and performance characteristics.

CHARACTERISTICS OF LIFE SAFETY ROPE

Rope Fibers

Nylon fibers – Ropes manufactured from nylon fibers have high strength, high resistance to abrasion, the ability to absorb shock loads and reasonable cost. Disadvantages are the strength loss, up to 23%, and weight gain that occur when nylon fibers absorb water. Exposure to acids will also damage nylon fibers.

Polyester fibers – Polyester fibers have the strength- and abrasion-resistance advantages of nylon, but the low-stretch characteristic of this fiber reduces its ability to handle a shock load. Water absorption is minimal, so performance when wet is virtually unaffected. Polyester also has a high resistance to ultraviolet degradation from sunlight. Polyester ropes are slightly heavier than nylon and tend to have less friction.

Polypropylene and polyethylene fibers – These fibers produce a rope that will float on water and are used for water rescue throwlines. Because of the low strength and durability of these ropes, the manufacturers warn that they should not be used for rappelling, hauling heavy loads or in rescue systems. Characteristics of these two fibers include good resistance to most chemicals and low resistance to deterioration when exposed to sunlight.

Rope Fibers Comparison Chart

Fiber Type	Strength	Stretch	UV Resistance	S.G.*	Melt Point	Cost
Nylon	high	high	good	1.14	219-254°C	moderate
Polyester	high	low	good	1.38	256°C	moderate
Polypropylene	low	low	poor	0.91	170°C	very low
Polyethylene	low	low	poor	0.93	135°C	very low
Aramids	very high	very low	fair	1.44	500°C**	very high
HMPE	very high	very low	fair	0.96	135°C	very high
LCAP	very high	very low	fair	1.41	330°C	very high

* Specific gravity

** Aramids decompose rather than melt

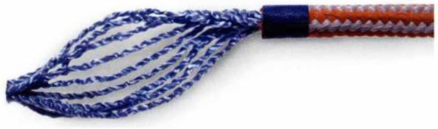
Aramid fibers – Kevlar®, Technora® and Twaron® are the most common brand name fibers in the aramid group. They offer high strength and high-temperature resistance but have extremely low elongation characteristics. Kevlar fiber ropes were found not to survive well in situations that require repeated bending, therefore Technora and Twaron have become the preferred fibers for life safety ropes. A unique feature of the aramid fiber is its resistance to flame and melting; rather it decomposes at approximately 500°C. Technora® has become the fiber of choice for fire resistant escape lines and life safety ropes used in fire ground applications.

HMPE fibers – High-Modulus Polyethylene fibers, such as Spectra® and Dyneema®, offer high strength and light weight. Because of their low thermal properties, ropes manufactured from these fibers are not recommended for rappels or rope systems. These fibers are frequently added to river rescue throwlines to provide added strength in small diameter ropes where flotation is also an important characteristic.

LCAP fibers – Some interest has been shown in Liquid Crystal Aromatic Polyester fiber, known more commonly by its trade name Vectran®. It tends to be a stiff fiber and like the aramid fibers, very expensive.

ROPE CONSTRUCTION

Laid – Laid ropes, often called three-strand, were the traditional rope construction used in rescues. In the fire services it was usually $^{3}/_{4}$ in (19.1 mm) manila and in mountain rescue it was $^{7}/_{16}$ in (11.1 mm) nylon, usually Goldline Mountain Lay. Because of the way that the strands twist in a laid rope, load-bearing fibers are exposed at the surface. When the rope abrades, these load-bearing fibers are cut, reducing rope strength. Laid ropes tended to stretch more and were prone to serious tangling and tended to cause rapid spinning during free-hanging rappels.



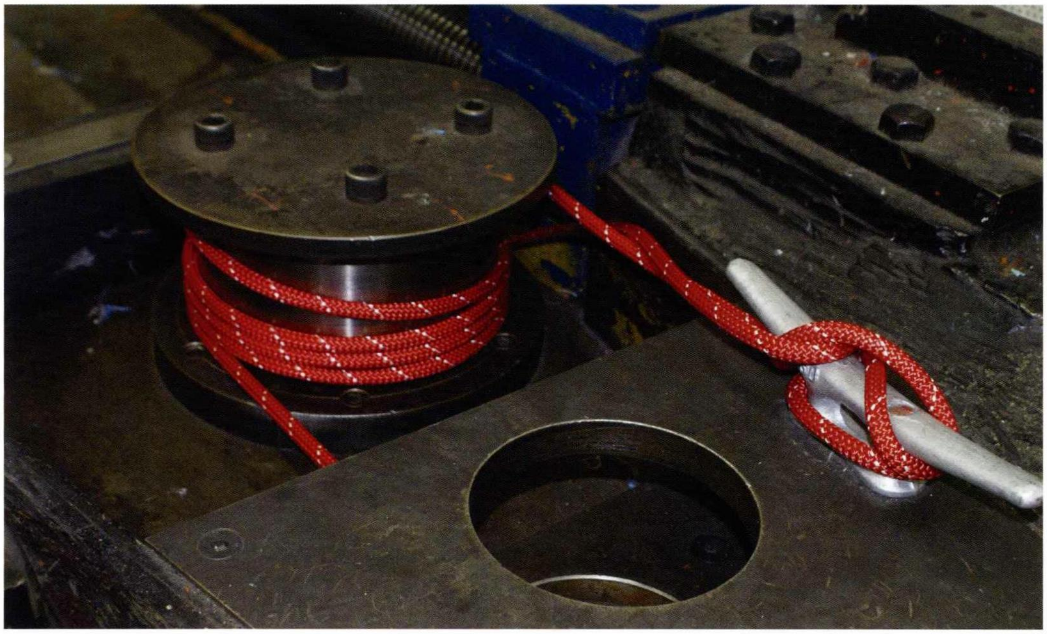
Kernmantle – Ropes with a core (kern) and a sheath (mantle) are the most common type of rope construction used in today's rescue ropes. Kernmantle construction provides a combination of high abrasion resistance and ease of handling. The core is made of parallel bundles of fibers and is the primary load-bearing part of the rope. The sheath holds the core bundles together and provides protection. The manufacturer will braid or twist the bundles in the core to give the desired elongation under load, depending on the rope's intended purpose. A low-stretch rope for rescue or rappelling will have very little twist. A sport climbing rope will have the core fibers twisted or braided to provide the rope's energy-absorption capability. The percentage of the load carried by the core of a kernmantle rope varies from 70% to 90%, depending on the brand of the rope and its diameter.

Braid on braid – Also called double-braid, these ropes typically have one hollow braided rope inside of another. This is a common construction for yacht ropes. Double-braid ropes can have as low as 50% of the load carried by the core (the inner braid) with the rest carried by the sheath. While seldom used in rescue systems, this construction is often used for specialty ropes, such as water rescue throwlines and ladder halyards.

Block Creel – In a rope with block-creel construction, the fibers run the entire length of the rope without any splices. This is a more expensive method of rope construction but provides a higher quality of rope. NFPA 1983 specifies block-creel construction for life safety ropes.

Rescue Rope Specifications

A rope's specifications are a compromise. Improvement in one area usually requires giving something up elsewhere. Since rope is essentially a narrow fabric woven on a gear driven braider, any specification is a range. Over the years we have seen rope brands that are very consistent and others that have varied widely.



A bollard is used to terminate the rope when testing its tensile strength. Teufelberger Ropes

Tensile Strength

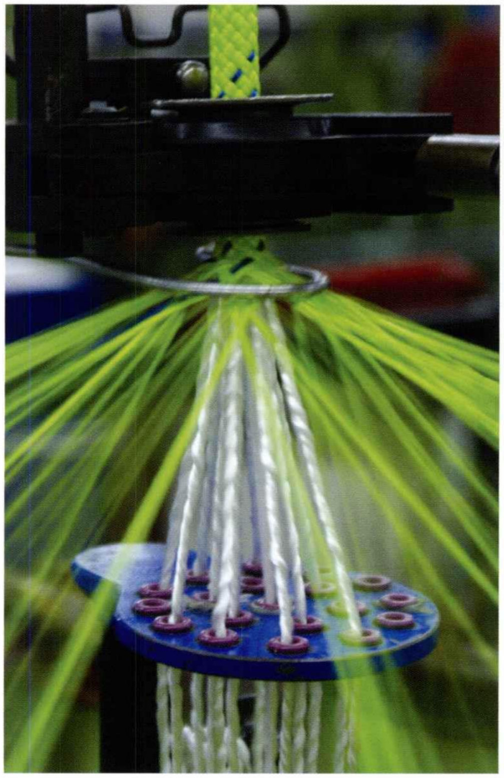
Rope strength varies directly with rope diameter; the thicker the rope, the stronger it is. But along with the increase in strength comes an increase in weight and bulk. How strong of a rope you really need depends on how you plan to use the rope and to what strength-weakening factors the rope will be exposed.

Tensile strength is the amount of force the rope will hold before it breaks. The manufacturers of rescue rope use Cordage Institute Standard CI 1800 as the test method for the tensile strength of low-stretch and static kernmantle rope, the most common construction for life safety ropes.

7/16 (11mm) Rope – NFPA 1983 was modified to allow for a 7/16 in (11 mm) General use rated rope. Today, CMC's G11 Lifeline (polyester sheath/nylon core) and Sterling's Tech 11 (Technora sheath/nylon core) are both certified to the General use standard. Likely, other cordage manufacturers will follow. This change allows a lighter weight rope and hardware kit while still maintaining the General use level of performance.

As important as the initial strength of the rope is what the user does to degrade that strength. Ropes do age and the decrease in strength varies directly with the amount and type of use. The knots we use to make the rope a functional tool reduce its working strength. So does bending the rope over edges, getting some ropes wet, overloading ropes and a variety of other actions that damage the fibers.

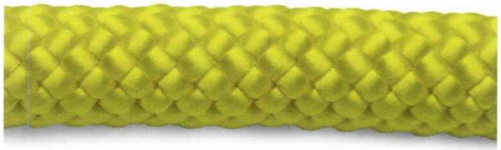
CMC G11™ Lifeline
NFPA, G-rated 11 mm rope



Teufelberger Ropes

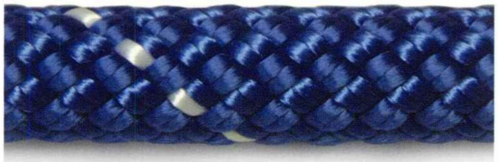
Sheath Construction

A carrier or bobbin is a moving spindle that holds the yarn for the sheath when manufacturing a kernmantle rope. As the carriers circle in and out, they weave the sheath around the core of the rope. Depending on how the carriers are loaded, the resulting sheath may have 16, 32 or 48 strands. The sheath can also have a one-over/one-under pattern or a two-over/two-under pattern. Generally a 48-strand sheath has a very smooth appearance and when viewed from the end of the rope, the sheath appears proportionally thinner compared to the core. The thicker strands in a 16-strand sheath have a rougher feeling surface and the sheath shows more material when viewed in the cross section (see Figure 05-1).



One-Over/One-Under Sheath Construction

The sheath design affects the handling, sheath slippage, abrasion resistance and knotability of the rope. The rope manufacturer selects the number of strands and the pattern they feel makes for the best-performing rope. For example, the manufacturer of a 48-strand sheath rope will say that the smoother sheath provides better abrasion resistance, while the manufacturer of a 16-strand sheath rope will say the more robust sheath provides greater abrasion resistance.



Two-Over/Two-Under Sheath Construction

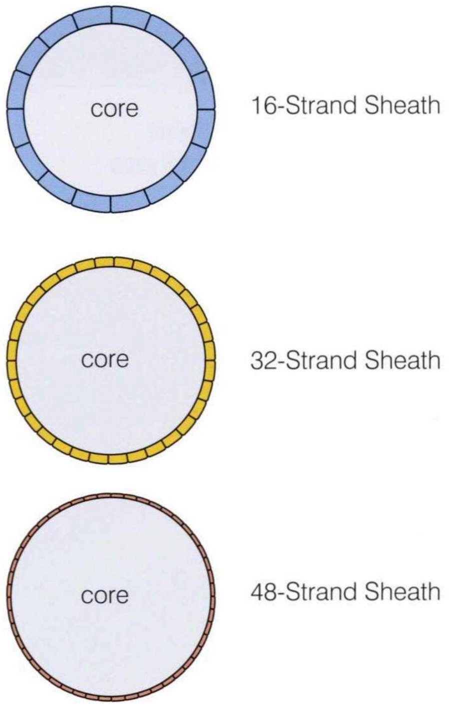


Figure 05-1: Cross Section of Ropes Showing Sheath Thickness

Rope Diameter Conversion Chart

Inches	Approx. mm	Actual mm
$^{1}/_{4}$	6	6.35
$^{5}/_{16}$	8	7.94
$^{3}/_{8}$	10	9 .53
$^{7}/_{16}$	11	11.10
$^{1}/_{2}$	12.5	12.70
$^{9}/_{16}$	14	14.29
$^{5}/_{8}$	16	15.88

Sheath slippage can be an issue on some kernmantle ropes. It is usually noticeable at the end of the rope when a length of the sheath slides past the core. While that can easily be remedied with a hot cutter, if the sheath slippage causes the rope to increase in diameter going into a pulley or through a Prusik hitch, a jam could result.

CMC developed a test for sheath slippage that consisted of taking a 25 ft length of rope and attaching it to a solid anchor. The other end was cut to make it easy for the sheath to slide past the core. A two-wrap Prusik hitch was pulled down the rope and the amount of sheath past the core was measured. One brand had no slippage at all, while some other brands produced 12 or more inches of sheath past the end of the core.

Several cordage manufacturers are developing new life safety ropes which connect the core and sheath to eliminate sheath slippage. Processes such as a bonding component or interweaving are being tried.

Rope Diameter

American rope manufacturers specify rope diameters in inches, except for recreational climbing ropes and accessory cords which are in millimeters. The current test method to determine the diameter of a kernmantle rope can be found in the Cordage Institute's Standard CI-1800. European ropes are all in millimeters. The following chart shows the rope diameter equivalent. NFPA 1983 uses metric sizing for all ropes and rounds up to the next half millimeter.

Larger diameter ropes are stronger, easier to grip and provide more friction for a slower rappel. They can have a greater safety factor because of their higher strength and abrasion resistance. Smaller diameter ropes are less expensive, lighter in weight, less bulky and fit a wider variety of rope rescue accessories, particularly equipment with lower weight, size and cost.

Abrasion Resistance

The history of mountaineering and caving accidents demonstrates that cut ropes are usually due to abrasion. Failure occurs due to strength loss in the rope when the rope abrades over an edge or receives an impact load while bent over an edge.

A rope that has a high resistance to abrasion retains its strength longer and is a safer as well as a more economical rope. The use of edge protection will further increase safety and rope life, but it is never possible to eliminate all sources of wear.

In the field, a rope suffers abrasion in such a wide variety of ways that it is not possible to design a laboratory test that approaches reality. Most of the manufacturers have conducted tests of their product in comparison with some of their competitors' ropes, but at this time there is no standard test method nor has there been a published test involving all of the ropes currently in use and conducted using any one test method. Studying the tests that have been published, we have observed the following trends:

- Static and low-stretch kernmantle ropes perform better than ropes of other construction
- In general, the stiffer a kernmantle rope is, the greater its abrasion resistance
- American manufactured ropes generally have better abrasion resistance than the European rescue/caving ropes, probably due to the heavier sheaths

Elongation

Elongation, or stretch, exists in all ropes and is measured as the percentage of increase in rope length under a given load. Ropes with low elongation are preferred for rappels and rescue systems because of the movement inherent when a load is placed on the rope. When the person on rappel or the litter tender transfers the weight from the ground to the rope, the load will descend some distance based on the elongation of the rope and the mass involved. The more rope above the person on rappel or above the litter, the further they will drop until the elongation is removed from the rope. With a raising system, the situation is reversed and the elongation must be removed from the rope before the litter system moves. The higher the elongation percentage of the rope, the less efficient the raising system will be.

Life safety ropes are classified by the amount of elongation under load. CI 1801 defines a ***static*** rope as having a maximum of 6% elongation at 10% of its minimum breaking strength (MBS). The definition for ***low-stretch*** rope is an elongation greater than 6% but less than 10% when a load of 10% of the MBS is applied. To provide more practical information for the user, NFPA 1983 requires that the rope's label provide the elongation figures at 300 lbf (1.35 kN), 600 lbf (2.7 kN) and 1,000 lbf (4.4 kN).

Energy Absorption

Dynamic ropes, such as those used by recreational rock climbers, have a much higher elongation percentage as the function of the rope is to absorb the energy of the climber's fall by stretching. Energy absorption relates directly to the rope's ability to stretch. The higher the elongation percentage, the more energy the rope can absorb. Static and low-stretch life safety ropes have a lower elongation percentage and as a result should not be used to belay a lead climber. When used with an appropriate belay device, static and low-stretch ropes are preferred for system belays as the lower elongation minimizes the distance the litter and tender falls while being caught by the belay.

Knotability

Because of the higher loads encountered in rescue systems, a balance is needed between a knot being easy to tie and easy to untie after use. A soft, flexible rope ties easily and the knots can be set tight by hand, but those knots will become impossible to untie after loading. A stiff rope may be hard to work with and a knot cannot be set tight by hand, creating a possibility of it coming untied or slipping before the knot has a chance to set. But the knot is easier to remove from the rope after loading.

Handling

Handling, or "hands", refers to the ease of working with a particular rope. A soft rope is easier to work with and, as mentioned above, knots are easier to tie and to set tight (but also harder to untie). A softer rope not only fits into a smaller rope bag but is much easier to stuff. Rescue team members that do not work with rope frequently usually prefer the easier to handle ropes.

Despite those advantages, many experienced rescuers prefer a stiffer rope for the added abrasion resistance and durability. A stiffer rope also provides more control for a lowering or during a rappel. The pit ropes used by cavers tend to be exceptionally stiff to make ascending the rope more efficient.

Color

Different colors of ropes help with rope management during the rescue. You can specify which rope to pull by color. While this can also be done by a rope number on the rope I.D. marker, you may not have the end of the rope nearby when you need it. Some departments use color to indicate rope length or the year placed in service. We feel that putting this information on the rope end is adequate and that the color variations are better used for rope management.

Bright colors are easier to see under low light conditions and subdued colors are available for military and law enforcement applications. One observation we received from a large sheriff's SWAT team was that a black or olive drab green rope hanging below their helicopter was hard to see against the blue sky. They preferred the visibility of a brightly colored rope for their flight operations.

A rope with a sheath color other than white is easier to inspect. If the white core fibers become visible, then the presence of damage to the sheath and possibly to the core is easier to detect.

WEBBING

Webbing is essentially a narrow fabric and comes in a variety of widths and constructions. Most webbing manufactured is a solid, flat material, which rescuers refer to as ***flat web,*** as opposed to ***tubular web,*** which appears hollow when viewed from the end. One-inch shuttle loom tubular web made to Mil-W-5625 had been the rescue industry standard, but over the years other types of web have gained acceptance. Webbing is available in nylon and polyester and the characteristics of those fibers were discussed previously (see Rope Fibers on page 28).

Tubular web is hollow and tends to be softer than flat web. The strength of both products depends on how much material is included. Common one-inch tubular web made to the old mil-spec is usually rated at 4,000 to 4,500 lb (17.8 to 20 kN). Add more fibers and the web becomes stronger but also wider and thicker. One-inch flat web used for rescue is rated at 6,000 lb (26.7 kN). Some flat web can be very stiff, so you should verify its ability to hold a knot before placing it in service.

For many years, webbing was manufactured to a mil-spec standard. With the government moving to commercial standards, the mil-spec for nylon tubular webbing has been replaced by PIA-W-5625F of the Parachute Industry Association.

Shuttle loom web, sometimes called spiral stitch, was the preferred web for rescue applications. With shuttle loom, the strands spiral around the web. If flattened out, the web does not appear to have an edge seam.

Web Length Color Coding

We have found more than one standard color code, but this one is used by most of the departments we contacted.

Color	Web Length
Green	5 ft (1.5 m)
Yellow	12 ft (3.5 m)
Blue	15 ft (4.5 m)
Orange	20 ft (6.0 m)

In some cases, 20 ft webbing will be red.

Early versions of needle loom web were suspect. The web has a lock stitch down one edge, which can be seen if the web is flattened out. Often the web was not a very tight weave, and this added to the concern that the web would unravel if the edge was abraded through the stitch.

In fact, versions of needle loom have been around for many years in the climbing and rescue fields. Needle loom machines are much faster than the shuttle looms, and the manufacturers are not replacing the shuttle looms. As a better quality of needle loom tubular web became available, testing by the manufacturers and users demonstrated that its performance was close to that of the shuttle loom. This has been verified by several years of field use with no incidents to indicate that the performance of the needle loom web was less than satisfactory.

Sewn web slings have been in use for several years. Anchor straps for rescue are usually 1 3/4 in (44.5 mm) web with D-rings on each end. Slings with loops sewn along the length, such as the Forrest Daisy Chain and the CMC Multi-Loop Straps, are a real convenience. Reputable commercial sewers test their products thoroughly and can provide strength specifications and consistent quality. Some manufacturers use a contrasting color of thread at key points to help recognize thread wear.

ROPE USE AND CARE

Life Safety Rope Logs

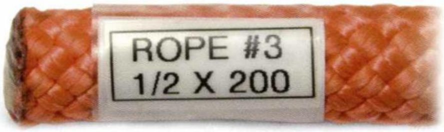
Keeping track of the rope's history is a very important element in knowing whether the rope is in good condition or not. NFPA 1983 requires that the user instructions for a life safety rope include a sample rope log.

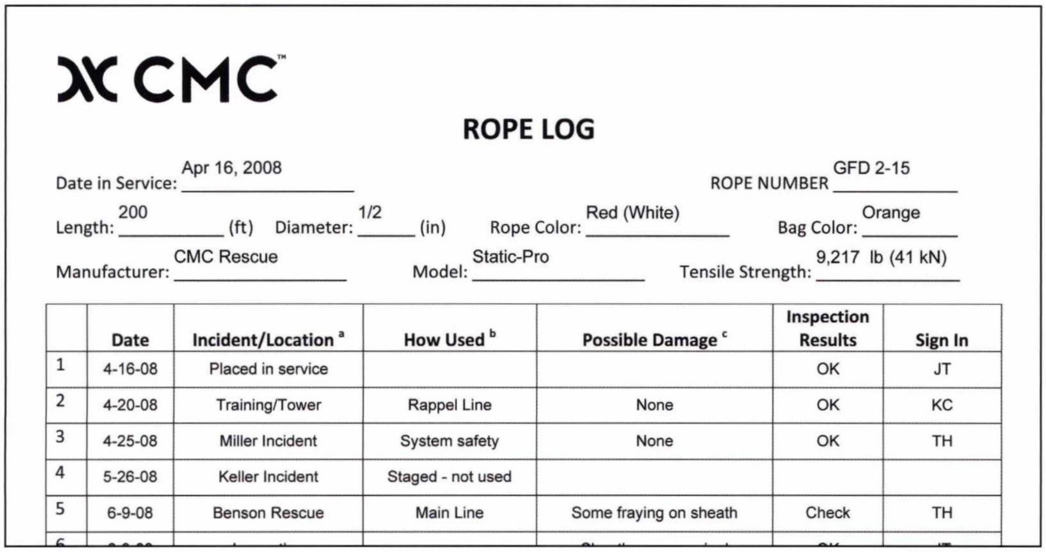
Start a rope log for each of your ropes. Log the rope out when it leaves the rescue vehicle and back in when it returns. Note the type of use made of the rope and any suspected problems, such as fraying or exposure to rock fall. Report any shock load, so that the rope can be retired. A rope should be inspected before it is placed back into service, even if there is no record of possible damage.

Some teams keep the rope log in a binder where they store the ropes, either in the rescue truck or the station. Other teams prefer to keep the rope log in a pocket on the rope bag, although that exposes the rope log to all the wear, dirt, mud and water that the rope bag will see.

When you buy a new rope, inspect it carefully before placing it in service. Make sure that the ends were adequately sealed when it was cut. If the manufacturer has provided any literature, be sure to read it carefully and save it. A new rope does not need to be broken in but will have less friction due to the manufacturer's lubricant on the fibers until it has seen some use.

Mark the end of the rope with the information you want on it, such as the rope number, department name, date in service, the diameter or length. Marking one end of the rope A and the other B helps track usage and can identify which end to start looking from for possible damage. White tape





CMC

ROPE LOG

Date in Service: Apr 16, 2008
ROPE NUMBER GFD 2-15

Length: 200 (ft) Diameter: 1/2 (in) Rope Color: Red (White) Bag Color: Orange

Manufacturer: CMC Rescue Model: Static-Pro Tensile Strength: 9,217 lb (41 kN)

	Date	Incident/Location [a]	How Used [b]	Possible Damage [c]	Inspection Results	Sign In
1	4-16-08	Placed in service			OK	JT
2	4-20-08	Training/Tower	Rappel Line	None	OK	KC
3	4-25-08	Miller Incident	System safety	None	OK	TH
4	5-26-08	Keller Incident	Staged - not used			
5	6-9-08	Benson Rescue	Main Line	Some fraying on sheath	Check	TH

Figure 05-2: Example of a completed rope log.
A blank rope log is available as a pdf at cmcpro.com.

covered with clear plastic tape will work. We use a wire marker tape, called Rope I.D. Markers by the rescue vendors, which allows us to type the name for clarity. A fine point marking pen will make a dark, easy-to-read marking.

Cover the tape with shrink tube or several coats of clear rope end sealant. One brand is Whip-End Dip, which comes in a water-based, environmentally kind formula, but many users have found the new formula does not work as well. StarBrite liquid electrical tape or tool dip will also work. We recommend starting with a thin coat to seal the I. D. Marker and then adding several more coats. None of these products have been tested to determine if they cause any strength loss in the rope, which is not important for the end of the rope, but would be for marking the middle of the rope.

Life Safety Rope Storage

We have found the best way to store a rescue rope is in a rope bag. The bag protects the rope while keeping it ready for immediate use. The rope length, diameter and number can be marked in large letters on the outside of the bag. Rope length or type can be identified by using different color rope bags. Ropes and rope bags should be stored in a cool, dry place out of direct sunlight. They should be kept away from chemical atmospheres, such as those found near batteries, engine exhaust and hydrocarbons.

When putting the rope into a rope bag, it is essentially piled in. Start by attaching the rope to the bottom of the bag so that you do not lose the bag if you throw it. With the CMC rope bags you can push the end of the rope through the bottom and tie an overhand knot in the outside carabiner loop or tie the end of the rope to the loop inside the bottom of the bag. Some like having access to both ends at the top of the bag, so push a loop in the bag leaving a short length of one end at the top, and then stuff the rest of the rope into the bag. Choosing a slightly oversized bag makes stuffing the rope easier and can leave room for web or a gear bag.

With the end attached, start pushing the rope into the bag. Remember to pack it down occasionally, so the bag will fill evenly. To finish, tie the end to the carabiner loop on top, so that it will be easy to find.

Life Safety Rope Deployment

Another advantage to a rope bag is ease of deployment of the rope. For a rappel, anchor the end of the rope and toss the bag, the rope will feed out. If there is a concern with striking the subject or the need to negotiate brush, the take the rope bag with you. It will feed best if clipped to your harness but can be worn on the back on lower angle terrain. For a rope system, the bag stays at the system and the rope feeds out.

Inspecting Life Safety Rope

The decision to retire a rope or to keep it in service relies on good judgment that comes only from experience in working with rope. Inspecting a life safety rope involves visually looking for damage, feeling for damage and checking the rope's history in the rope log.

Inspect a new rope before it is put into service and then after each use. The inspection should be done by an experienced person deemed qualified by the agency/organization. A complete inspection includes a visual and a tactile inspection.

Visually inspect the sheath to identify chafed areas, glazed surfaces, discoloration or variations in diameter. These areas should receive additional scrutiny during the tactile inspection. Look for areas of abrasion or cuts in the sheath where the core is exposed or enough of the sheath is worn that its ability to protect the core is compromised. The tactile inspection should be done with tension on the rope. Feel for variations in size and soft or hard spots that could indicate damage to the core or rope that has been overstressed. If any of the above are noted, the rope should be retired from service. If the rope has been subjected to shock loads, fall loads or abuse other than normal rappel or rescue training, the rope should be retired from service.

Each rope should be inspected before being used even if the rope has never been placed in service. Keep ropes away from acids, alkalis, exhaust emissions, rust, hydrocarbons or other strong chemicals. Do not allow rope to be shock loaded or used over sharp edges.

It is impossible to state when to retire a rope because of the many variations with each rope. ***If you have any doubts about the integrity of a rope, destroy it!***

For more information on rope inspection, see ASTM F1740 *Standard Guide for Inspection of Nylon, Polyester, or Nylon/Polyester Blend, or Both Kernmantle Rope, or* NFPA 1858: *Standard on Selection, Care, and Maintenance of Life Safety Rope and Equipment for Emergency Services.*

Life Safety Rope

The CMC School uses the following procedure to wash ropes. Rinse off any excess dirt with a hose. Then soak the rope for about 30 minutes in a plastic tub of water with a mild soap (not detergent) added. Rinse the rope by pulling it through a rope washer twice. Hang the rope in a cool, shady place to dry.

When to Retire a Life Safety Rope

Section 5.5.2 of ASTM F1740 *Standard Guide for Inspection of Nylon, Polyester, or Nylon/Polyester Blend, or Both Kernmantle Rope* recommends 10 years as a maximum rope life. The committee felt that after 10 years of storage, it might be worth considering replacement of a life safety rope even though the rope had not been used. NFPA 1858: *Standard on Selection, Care, and Maintenance of Life Safety Rope and Equipment for Emergency Services* states to retire a rope at 10 years.

CMC had the opportunity to test rope stored for seven years by a Bridger Coal's (WY) mine rescue team. The rope had been stored on the spool in a cool, dry location for seven years. The samples were 12.5 mm ($^1/_2$ in) diameter low-stretch kernmantle rope. The manufacturer's new rope tensile strength rating was 40.3 kN (9,059 lbf). For comparison, the independent lab tests on new rope averaged 47.0 kN (10,566 lbf). The test results from the Bridger Coal samples suggest minimal strength loss when the rope is properly stored.

Break #1	50.2 kN (11,285 lbf)
Break #2	47.5 kN (10,678 lbf)
Break #3	49.3 kN (11,083 lbf)
Average	49.0 kN (11,015 lbf)

What happens when we actually take a life safety rope out into the field and use it in the dirt, sun, rain, running it through pulleys, ratchets and descenders? Rope is a textile product and abrasion on the fibers through bending the rope, tying knots, running it over rough surfaces and loading/unloading cycles cause wear that decreases the strength of the rope. The unknown factor is how quickly this microlevel damage adds up to a significant decrease in the working strength of the rope.

The National City (CA) Fire Department sent us a rope they described as old and well used. They said it was the worst looking of the ropes they had in service and its acquisition preceded any recordkeeping. The marker tape indicated the rope was BlueWater II manufactured in 1983. BlueWater's catalog specifies a 34.1 kN (7,666 lbf) tensile strength for 12.5 mm ($^1/_2$ in) diameter BlueWater II. Tested by Wellington Commercial Cordage, the results showed an approximate 15% strength loss after nearly 10 years.

Break #1	28.7 kN (6,452 lbf)
Break #2	30.5 kN (6,856 lbf)
Average	29.6 kN (6,654 lbf)

Bruce Smith, co-author of *On Rope*, collected and broke more than 100 samples of used caving rope. Using the rope's history, each sample was categorized as like new, used or abused. Like-new ropes averaged a strength loss of 1.5% to 2% per year and used ropes 3% to 4% per year. Smith observed that "care of the rope has a far greater impact on a rope's life than age."

Rescue Rope Rules

The following safety rules for rescue rope use relate directly to actions that reduce the strength of a rope and safety of the rescuer.

1. Do Not Step On The Rope

Stepping on a rope laying on a deck or surface with open steel grating or other sharp edges can damage a rope. You should know where your feet are when working in the high angle environment for your own protection. Stepping on or in a rope flaked out for a lowering could get you tangled up in a loop when the rope moves.

2. Do Not Straddle The Rope

Standing over or too close to a loaded rope exposes you to possible injury if the system fails and the rope snaps back. Standing over an unloaded rope can be upsetting or painful if the rope is loaded without you knowing it. Even better, never allow anyone to stand in line with or on either side of a rope under tension.

3. Protect The Rope From Sharp Edges

Sharp bends reduce the strength of a rope. When the rope is loaded, bends greatly increase the effects of abrasion and can possibly cut the rope. Use edge protection or rig the rope differently.

4. Avoid Exposure To Chemicals

Anything harmful to nylon or polyester is not good for your rope. Store rescue ropes in a location where they will not be exposed to sunlight, heat or chemicals. If it is not safe for your hands, it is probably not safe for your rope.

While that information may allow you to calculate how much strength loss has occurred, it doesn't really tell you whether or not to retire the rope. You know how much strength you are losing, but you must then decide how much strength loss is acceptable before retiring the rope. As of today, there are no standards or suggested minimums for how strong a used life safety rope should be.

Aside from shelf life and strength loss, the other reason for retirement is damage or suspected damage. The inspection may find evidence of damage, or a team member may report that the rope suffered an impact load, was hit by a rock or smashed between the litter and the wall. If you do decide to retire the rope, take it apart and look inside at the damaged area to get a better understanding of how much abuse the sheath can take and still protect the core. More often than not, no damage to the core can be seen.

Again, if you have any doubt about the integrity of your life safety rope, retire it. No equipment replacement cost is worth putting a rescuer's life at risk.

PART
02
Rope Rescue Equipment

CHAPTER
06
Rope Rescue Hardware

TERMINAL LEARNING OBJECTIVE

The student will be able to describe the materials, use, and care of basic rope rescue hardware.

ENABLING LEARNING OBJECTIVES

1. Describe the criteria for selection of rope rescue hardware based upon how it will be used
2. Describe the use and misuse of different types of rope rescue hardware
3. Describe the inspection and maintenance of rope rescue hardware

NFPA® JOB PERFORMANCE REQUIREMENTS

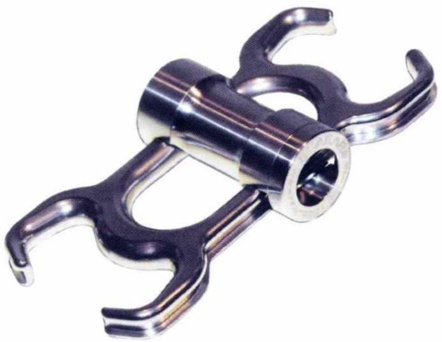
This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.2.3 | 5.2.7

LEGEND: Anchor Grip Load

CMC CLUTCH™ by Harken Industrial™

PETZL® I'D®



Conterra SCARAB®

lock off the descender. This feature is particularly useful when working on rope and making frequent stops or when both hands are needed to transition the edge when starting a rappel.

Some auto-lock descenders have a double-brake feature. On a single-brake, auto-lock descender, if the user squeezes or pulls the handle harder trying to stop, the rate of descent will actually increase. On a double-brake design, both releasing the handle or pulling harder will cause the descent to stop. The NFPA G-rated CLUTCH is rated for two-person loads.

The current models of auto-locking descenders are designed for single person loads. With some models, the manufacturer's instructions allow their use with a load of two persons or as a rescue system belay as an advanced technique for experienced users. CMC's MPD and CLUTCH and Petzl's MAESTRO all incorporate a pulley.

When used in place of the change-of-direction pulley in a 3:1 mechanical advantage (M/A) system, the locking mechanism acts as the ratchet in the system. This conveniently eliminates using a separate rope grab, such as a Prusik hitch, to hold the system while resetting. While the rope does slide through the descender when raising, it does so around a fixed object rather than a pulley. The system will be much less efficient than if a pulley were used at the anchor. The MPD, CLUTCH, and MAESTRO incorporates both the change-of-direction pulley and the ratchet.

Other Descenders and Brakes

The number of new descender designs increase every year. New descenders can often introduce significant improvements but are more expensive, can require more complex training, are heavier, can be harder on the rope, and can lack versatility. The Figure 8 or the Brake Bar Rack provides simplicity and versatility at a low cost. In addition, they can provide opportunities to become more familiar with fundamentals of rope rescue techniques.

Another descent control device is the SCARAB® Rescue Tool from Conterra. It combines some of the advantages of the Brake Bar Rack but is much closer to a Figure 8 descender in weight and bulk. It is available in stainless steel for 9 mm to 13 mm life safety rope and in a lighter, titanium model for 6 mm to 11 mm rope.

Inspection and Care

Compared to carabiners, ascenders and pulleys, Figure 8 descenders and Brake Bar Racks are pretty simple, both lacking small moving parts. As a result, they are easy to inspect and maintain. When muddy or dirty, they can be washed with water, using soap as needed, then dried. Auto-locking descenders need to be checked to make sure the moving parts are not bent or at risk of binding up.

Wear from abrasion is the primary cause of retirement. The industry rule of thumb suggests retirement of a brake bar or the Figure 8 when 10% of the material is missing. Any nicks or sharp spots can be smoothed with emery paper.

Inspecting the Brake Bar Rack should include checking both nuts on the U-rack and that the self-locking nut, which holds the bars on the frame, is not loose. If the rack has a welded eye, look for cracks in the weld. Straighten any minor bends in the frame and make sure that the bars slide freely.

PULLEYS

Pulleys are used to change the direction of moving ropes and to build mechanical advantage raising systems. Like the carabiners, you will want quality pulleys designed and built specifically for rescue. Many pulleys are labeled as rescue pulleys, but some are lightweight climbing models intended for crevasse rescue or load hauling on big wall climbs.

A pulley used for rescue should have a metal sheave (wheel) mounted on a bearing. Plastic or nylon wheels that do not have a bearing tend to deform under load. This can increase the friction or even stop the wheel from turning. If this happens, the friction from the sliding rope can wear a groove into the sheave. To minimize weight, most pulley sheaves are aluminum. A steel or stainless steel sheave is heavier but allows the use of rope or steel cable if you need such a dual purpose pulley. Most manufacturers of rescue pulleys offer single and double sheave models, and some even offer triple sheave models.

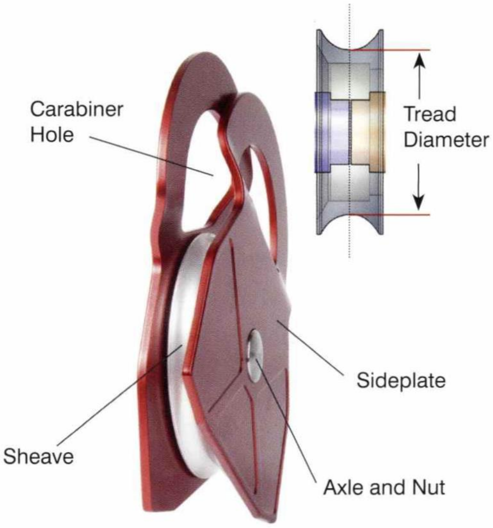


Figure 06-9: Parts of a Pulley

The NFPA 1983 performance requirement for a general-use pulley is 36 kN (8,093 lbf) and for technical use 18 kN (4,046 lbf). The rescue pulleys made today are often stronger than the other links in the system. What is important to remember about pulley strength is that when using a pulley for a change of direction, the load may be multiplied up to twice as much as the system load.

Pulley Size

Pulley size is determined by the diameter of the sheave at the tread, the actual diameter that the rope bends around. On early models of rescue pulleys, the size was determined by the outside diameter of the sheave. The other size dimension is the width of the sheave which specifies how large a diameter of rope will fit in the pulley without undue friction on the side plates.

Any bend in a rope decreases its strength, including bending around the sheave of a pulley. A sheave diameter of three times the diameter of the rope causes only a minimal loss in rope strength. In the case of $^{1}/_{2}$ in (12.5 mm) rope, the tread diameter of the sheave should be $1^{1}/_{2}$ in (38.1 mm). For $^{7}/_{16}$ in (11 mm) rope you should use a pulley with at least a $1^{5}/_{16}$ in (33.3 mm) tread. To minimize rope wear from bending, the Cordage Institute recommends a minimum sheave diameter of eight times the rope's diameter[1]. For a $^{1}/_{2}$ in (12.5 mm) rope, this would require a 4 in (102 mm) diameter sheave. Also, the larger the sheave, the more efficient the pulley. This is due to the rope bending less tightly and because the rope effectively has a better mechanical advantage over the friction that resists turning.

While a smaller pulley may sacrifice a little efficiency and some rope strength, the loss may well be offset by the reduction in equipment weight. Lighter pulleys are easier to transport and store and less likely to hang up on rock nubbins or structural parts during a raising.

Because of their higher efficiency, most rescue pulleys have sealed ball bearings. Oilite® bushings were popular for a while, mostly due to their lower cost, but the greater efficiency of a ball bearing pulley made up for the price difference for most users. The other advantage of a ball bearing is its low maintenance—provided it is fully sealed.

Tests conducted in the development of an NFPA standard for pulley efficiency indicated the most significant variable was the rope rather than the bearing type or pulley sheave size. Most of the pulleys available today are close to the same performance level for efficiency, and the minor differences only become noticeable as the number of pulleys in a system increases.

The side plates on rescue pulleys are designed to rotate, allowing the pulley to be attached anywhere along the rope. Stainless steel sideplates provide high strength and excellent environmental resistance. Aluminum side plates are generally thicker material, allowing a more rounded edge than found on the steel side plates. The hole in the side plate should be large enough to allow the gate of a carabiner to rotate through.

A unique design on the CMC Rescue Pulley and CMC ProTech™ Single Pulley uses the side plate as part of the pulley's axle. This provides a significant increase in strength for a small pulley and also

Effect of Bends on Rope Strength

One of the CMC School research projects for the International Technical Rescue Symposium looked at the effect of tight bends on rescue rope. A bight of new $^{7}/_{16}$ in (11 mm) rope was looped around a bollard and pulled end to end. See Appendix H for the full test results.

Bollard Diameter	3σ Tensile	Strength Loss
4 in (10.16 cm)	13,690 lbf (60.60 kN)	Control
2 in (5.08 cm)	13,008 lbf (57.86 kN)	5%
$1^{1}/_{2}$ in (3.81 cm)	13,243 lbf (58.91 kN)	3%
1 in (2.54 cm)	10,903 lbf (48.50 kN)	20%
$^{1}/_{2}$ in (1.27 cm)	9,462 lbf (42.09 kN)	31%

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[1] The Cordage Institute Technical Information Service. Fiber Rope Technical Information Manual. Hingham, MA: Cordage Institute, 1993.

a flat side plate without any protruding axle to catch as the pulley moves across a surface. **Reeving only one side of a double pulley can create a sideways force on the side plate and has caused failure in a few cases and it is not recommended.**

CMC
MEETS NFPA 1983 (2017 ED) MBS 56 kN "G" Ø ≤ 13mm PART# 300301
56 kN
28 kN
28 kN
CMC
78 kN
39 kN
39 kN
2.6" SHEAVE

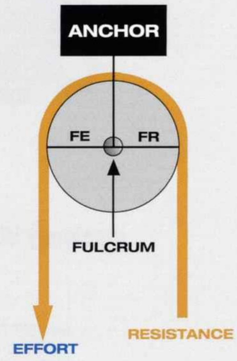
CMC Rescue Pulley and CMC PMP Swivel Pulley

Prusik-Minding Pulleys

When using a Prusik hitch with a round bottom side plate, rope drag often pulls the hitch into the top of the pulley, jamming the system. In the early 1980s, Arnör Larson suggested using a pulley with a squared-off bottom. The shape tended to keep the Prusik hitch at the bottom of the pulley, thus preventing the hitch from jamming. Most new pulley designs incorporate this capability, which coincidentally also works better when tending a Gibbs ascender type of ratchet.

How Pulleys Work to Provide Mechanical Advantage

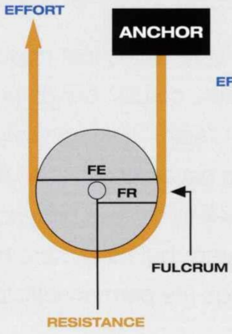
To understand how pulleys provide mechanical advantage in rope systems, it is helpful to first consider how levers work.

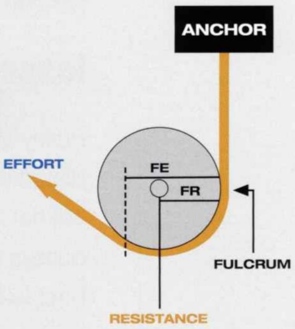


A **fixed pulley** can be viewed as a first class lever. The fulcrum is located at the axle in the center of the sheave, directly below the carabiner that connects the pulley to the anchor point. Because the sheave is round, the distance (FR) from the axle (fulcrum) to the point the rope leaves the sheave and goes to the resistance (load) is equal to the distance (FE) from the axle to the point that the rope leaves the sheave and goes to the effort (force). The two lever arms are equal, resulting in 1:1 MA and the reason a change-of-direction pulley does not increase the mechanical advantage of the system.

A **moving pulley** can be viewed as a second class lever. The fulcrum is located on the edge of the sheave directly below the point where the rope is attached to the anchor. One lever arm (FR) extends from the fulcrum to the pin, which is directly above the carabiner that attaches the resistance (load) to the pulley. The other lever arm (FE) extends from the fulcrum to the point where the rope leaves the sheave and goes to the effort (force). This lever arm is twice as long as the other arm, resulting in 2:1 MA. Moving pulleys increase the mechanical advantage of the system.

When the rope is pulled through a moving pulley at less than 180°, the rope leaves the sheave at a point closer to the fulcrum, shortening the lever arm and reducing the mechanical advantage created by the pulley. This also decreases the mechanical efficiency by pulling the system sideways instead of in a straight line.





CSR² Pulley

Swivel Pulleys

A combination of a pulley and a swivel helps keep the rope in line, particularly useful when using a high directional. By having the pulley and swivel incorporated into one unit, the working height that would be used by a separate swivel and carabiner is not lost. Consider using a swivel pulley to prevent twisting of the lines in a mechanical advantage system. Typical with this style of pulley is a side plate that can be opened without removing the pulley from the carabiner.

Self-Tending Pulleys

Whether a CMC CSR2 Pulley or other brand, self-tending pulleys feature an integral or attached cam that allows the rope to be pulled in one direction, but holds the rope when it is released. Primarily designed for vertical access in confined space applications, these double-sheave pulleys are most often used in a 4:1 M/A system. The 4:1 has enough mechanical advantage that a descender is usually not required when the system is used for a lowering. Since the pulley is typically connected to a high anchor point, most models use a tag line to release the locking mechanism and allow the system to be lowered.

Kootenay Ultra Pulley

Kootenay Ultra Pulley or Knot Pass Pulleys

Years ago, Russ Anderson designed an oversized pulley for passing the knot used to connect two ropes together. The extra width of the sheave made the pulley a good choice for high lines, particularly when multiple track lines were used. The carabiner holes at the bottom of the pulley provide connection points for the tag lines. The flat bottom on the pulley gave it a stable platform, allowing it to be used as an edge roller as well. Several companies now manufacture these large pulleys. One addition is a locking mechanism or pins to lock the sheave which allows the pulley to be used as a high-strength tie-off.

Inspection and Care

Pulley side plates that rotate should do so easily, but not feel loose. Check side plates for distortion, cracks, bends or elongation of the carabiner hole. While the sheave on most pulleys will not "spin," it should still turn freely. If the pulley has axle nuts, check for tightness. Some pulleys have witness lines that make checking the axle nuts easy. An air hose is probably to best way to remove dirt and dust from a pulley. Pulleys can be washed in soap and water if necessary, but make sure that they are dry before storing. Oilite bushings and sealed ball bearings are permanently lubricated, so lubrication is not required.

SWIVELS

The addition of a swivel in the rope system can help prevent the system's lines from becoming tangled and wrapping around each other. Swivels also allow the load to be easily rotated for better clearance through small openings.

While most rescue swivels meet the NFPA 1983 performance requirements for MBS, a load significantly less than the MBS can damage the ball bearing race with a resulting loss in efficiency. If you anticipate higher loads, look for a swivel that has the type of bearing designed for high load applications.

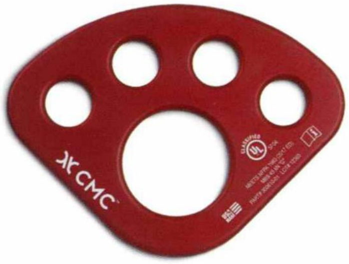
Swivel care and maintenance is essentially the same as for a rescue pulley.

Swivels

ANCHOR PLATES

Another Russ Anderson concept that was around in limited production for years is the rigging plate, which was originally used to connect the legs of a litter harness. The rigging plate was fairly large and had seven to twelve holes.

This looked to us as a good way to organize the various carabiners and hardware attached to a system anchor. We downsized the plate to four small holes and one large hole and began manufacturing the CMC Anchor Plate in aluminum and stainless steel. Whether it has three, four, or five holes and is called an anchor plate, bearpaw or RPM plate, it makes the system easier to set up and to manage when under load.

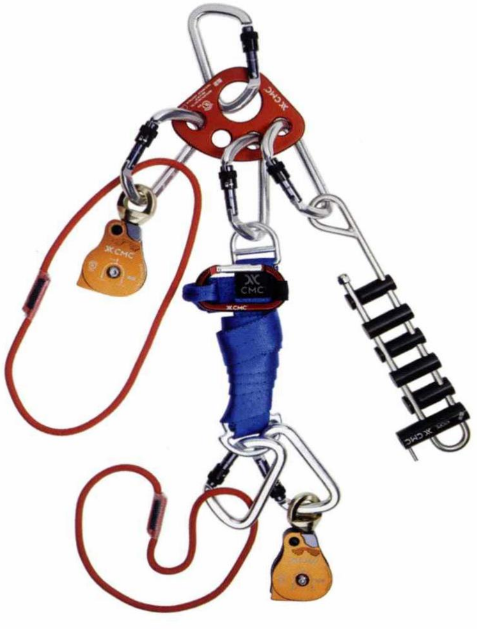


Anchor Plate

During one early training session, we added an anchor plate to the rope kit. We discovered that the use of the anchor plate was intuitive for most of the students and helped them set up rescue systems quicker and with fewer mistakes.

The small holes on the anchor plate keep carabiners from jamming together, making them easy to access when changing or adding hardware. The large hole acts as a collection point for rigging multi-point anchor systems.

The anchor plate can also be used to pre-rig the system. A common method is the RPM, which stands for rack, pulley and mariner (the Prusik hitch on a release knot). With the equipment needed for the system already connected to the anchor plate, just connect the plate to the anchor and your hardware is set up. The CMC School uses the setup shown in the photo.



An anchor plate can be used to pre-rig a system.

Gibbs Ascender

CMC Ascender

Climbing Technology
Quick Up Ascender

Climbing Technology
EVO Chest Ascender

540° Rescue Belay

Inspection and Care

Look for dents, cracks, or distortion in the anchor plate's holes. Nicks or sharp spots can be smoothed with emery paper. Minor bends in a stainless steel anchor plate can be straightened out. Wash as needed with soap and water.

MECHANICAL ASCENDERS

Mechanical ascenders are designed to hold a single person load while ascending a fixed line. The cam-type ascenders, such as the Gibbs Ascender and the CMC Ascender, are used by some organizations as the ratchet in a mechanical advantage system because their self-tending function makes them very efficient. Others rescuers use a Prusik hitch, which is lighter weight, less expensive and able to handle more of a shock load should any be placed on the main line. Ascenders should not be used as the haul cam in an M/A system as they could damage the rope if the load increases.

Inspection

Visually check all parts of the ascenders. Check the cams for cracks, wear and any sharp edges. Check the shell for sharp edges, cracks and any elongation of the pin hole. Make sure the pin is not bent and the indents hold the pin in place. Check any cables, springs, cords or chain for function or if they are missing or stretched out of shape.

540° RESCUE BELAY

The *540° Rescue Belay* is a device designed to arrest and hold a falling load. While significantly heavier and more expensive than the two loops of cord used for a tandem Prusik hitch belay, it is much easier to set up and operate consistently and can be released under load.

Care and Maintenance

See the manufacturer's instructions for specific information on the use, care, and maintenance of the 540° Belay. Be sure to check the spring on the back.

MULTI-PURPOSE DEVICES

With the introduction of the MPD, the concept of a multi-function device was created. While some pulleys incorporated a ratchet and some belay devices could be used as a change of direction, the MPD was the first device to combine a descent control device, a change of direction pulley with a ratchet, a rope system belay device, and a rappel device - all with NFPA certification. The CLUTCH and the Petzl MAESTRO® are examples of other multi-function devices.

CLUTCH

Due to its multi-function design, rescuers and rope access technicians both use the CLUTCH. The basic function is the same as other auto-stop devices, such as the Petzl I'D, and each have their unique features. Most auto-stop devices are designed for use with rope in a specific range of diameter sizes, which are marked on the device.

Features of the CLUTCH include:

- Ability to be rigged without disconnecting from the anchor or harness
- Acts as a descent control device for rappels or for lowering
- Incorporates a pulley for efficient raising systems or ascending
- Certified as a belay device for systems or a lead climber
- Opens with a double latch
- Certified to NFPA 1983 (G-Rated), ANSI Z359.4 and EN 12841/C, 341/2A, and 15151/8

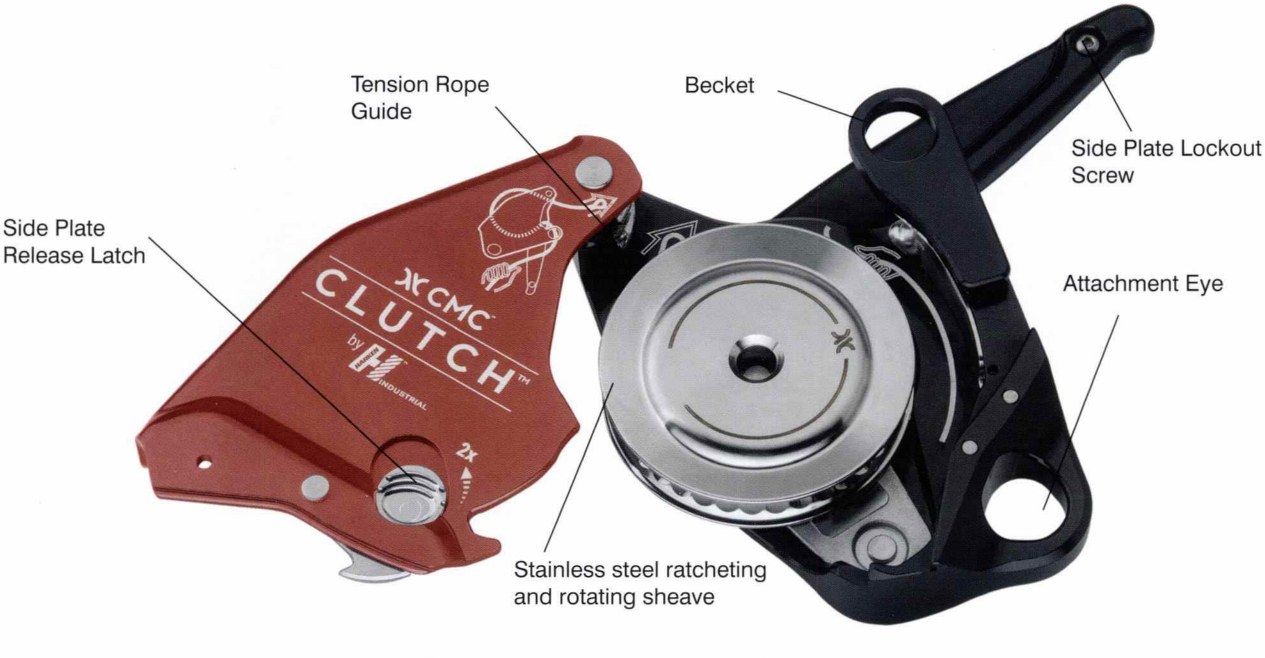

Tension Rope Guide
Becket
Side Plate Lockout Screw
Side Plate Release Latch
Attachment Eye
Stainless steel ratcheting and rotating sheave
CMC
CLUTCH
by
INDUSTRIAL
TM
2x

Figure 06-10: Key Parts of the CLUTCH

Rigging the CLUTCH

Before each use, check for cracks, excessive wear, corrosion, or foreign material that could affect normal operations. Move the Control Handle through its range of motion. Move the Control Handle to the Standby position and check that the Sheave Swing Arm moves freely. Then check that the Sheave is in good condition and freely rotates only anti-clockwise.

To rig the CLUTCH, open the side plate by pushing the Side Plate Release Latch two times. Move the Control Handle to the Standby position; see the position guide on the back. Load the rope according to the diagram marked on the inside of the CLUTCH and close the side plate. If not already attached, connect the CLUTCH to your harness or to an anchor. Push the Control Handle to the Stop position.

Confirm correct rigging by tugging on the side of the rope going towards the anchor. If the CLUTCH is attached to an anchor, tug on the rope going towards the load. With the handle in the Standby position, gradually apply a load to the CLUTCH. If descent is possible, check the rigging. If descent is not possible, the CLUTCH is rigged correctly.

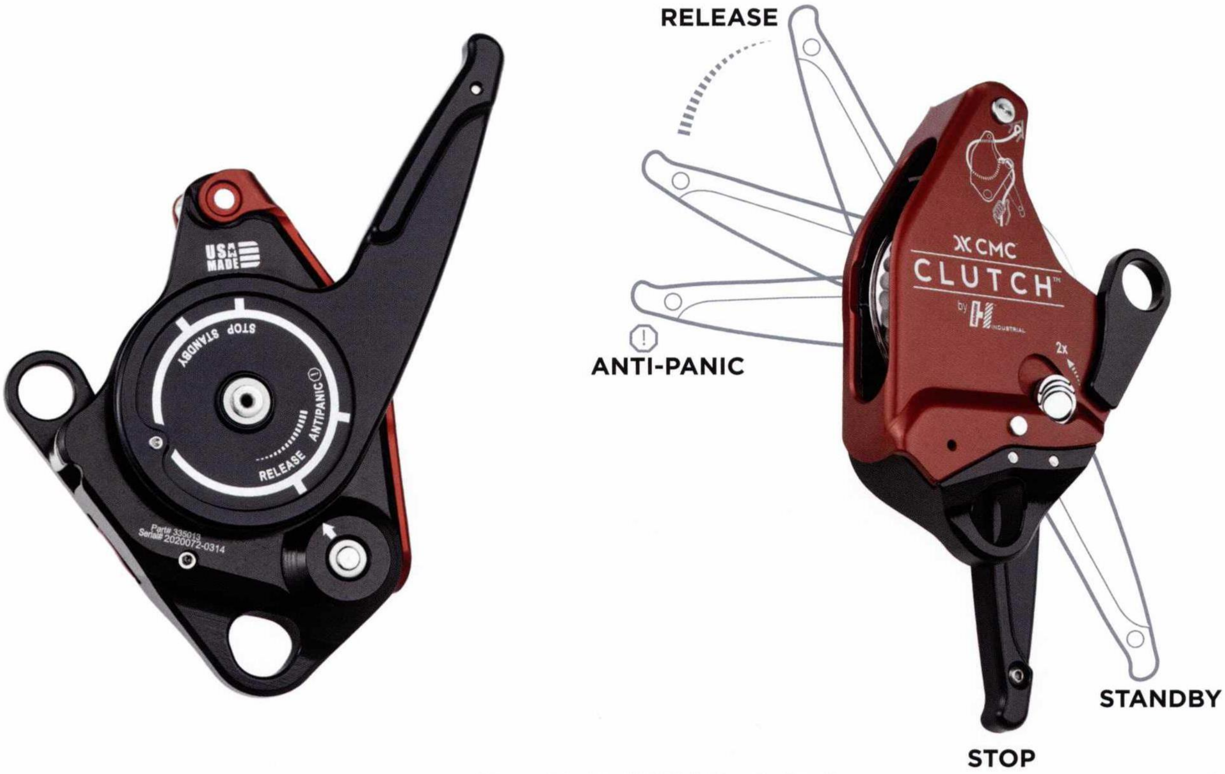
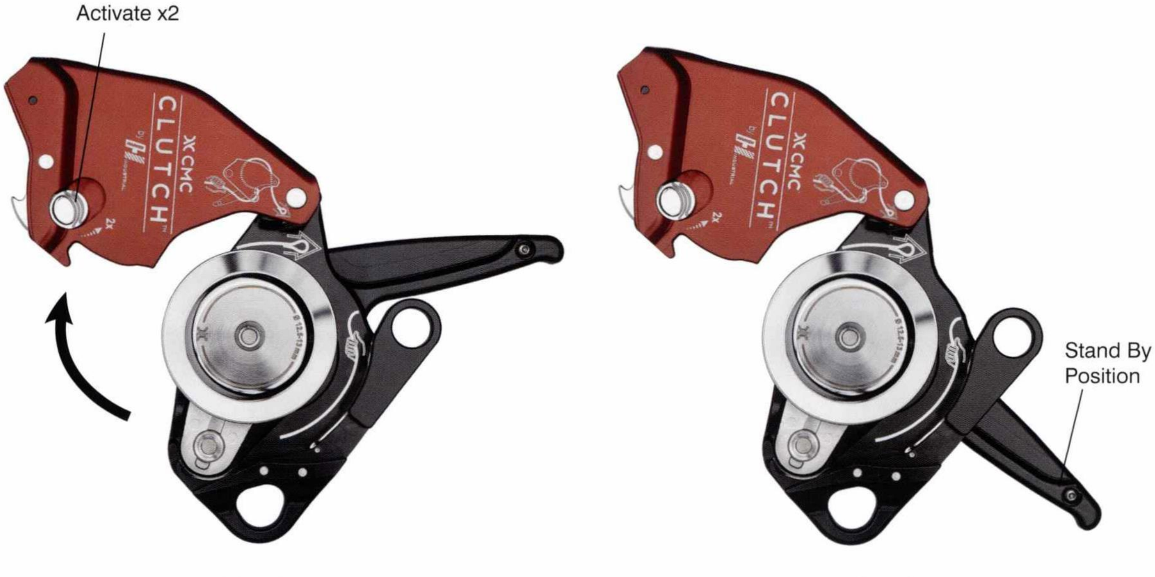
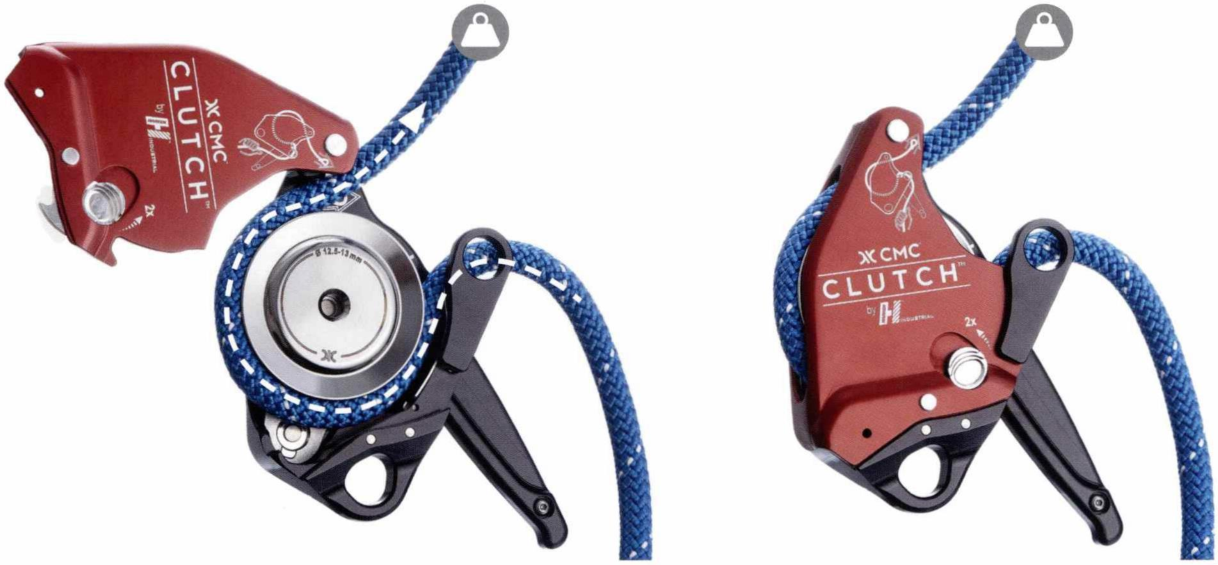


Figure 06-11: CLUTCH Handle Positions



Step 1:
Open the Side Plate by activating the Side Plate Release Latch 2 times.

Step 2:
Move the Control Handle to the Stand-By position.



Step 3:
Load the rope according to the diagram marked on the device, loading the Tail Side first to prevent the sheave from blocking the rope path when there's significant tail weight.

Step 4:
Close the Side Plate and secure the device to an appropriate attachment point or anchor with a locking connector.

Figure 06-12: Rigging the CLUTCH

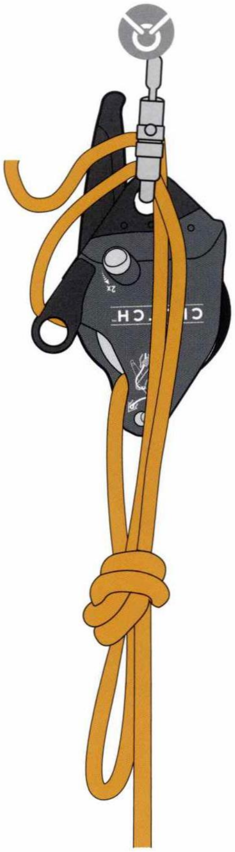


Figure 06-13: CLUTCH tied-off

In the case where a secure tie-off is necessary, secure the system by tying off the free end of the rope around the load/tension side of the rope with an appropriate tie-off method (see Figure 06-13). A minimum of 6 in should be maintained between the knot and the device

Learn more about the CLUTCH:

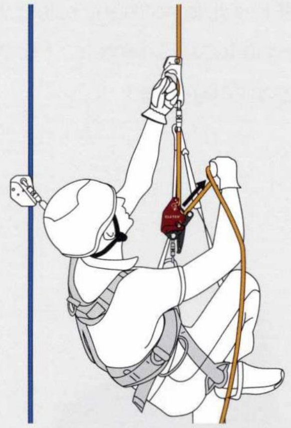
- Chapter 15 for using the CLUTCH in rope rescue system belays
- Chapter 16 for using the CLUTCH in lowering systems
- Chapter 17 for using the CLUTCH in raising systems
- Chapter 21 for using the CLUTCH for rappelling
- Chapter 22 for using the CLUTCH for ascending
- Chapter 23 for using the CLUTCH for lead climber belays

Inspection and Care

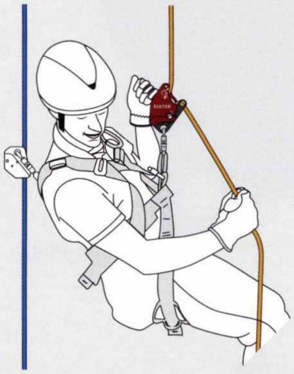
Clean and dry this equipment after each use to remove any dust, debris and moisture. Use clean water to wash off any dirt or debris. During use, carrying, storage and transport, keep the equipment away from acids, alkalis, rust and strong chemicals. Do not expose the equipment to flame or high temperatures. Store in a cool, dry location. Do not store where the equipment may be exposed to moist air, particularly where dissimilar metals are stored together. Ensure that the equipment is protected from external impact and keep out of direct sunlight.

For detailed information on using the CLUTCH, please refer to the CLUTCH manual, included with the CLUTCH or visit cmcpro.com/manuals.

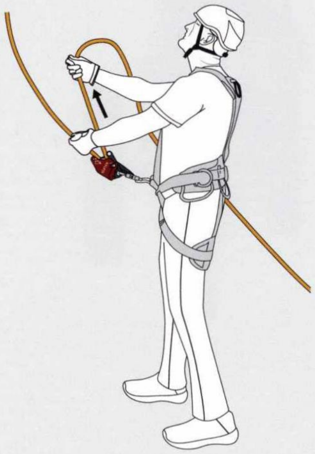
CLUTCH Use Examples



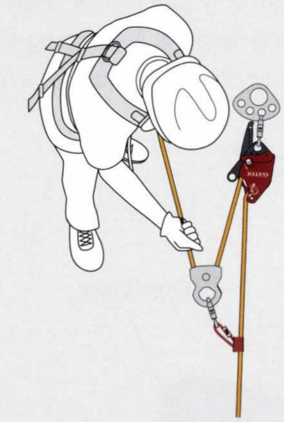
Personal Ascent



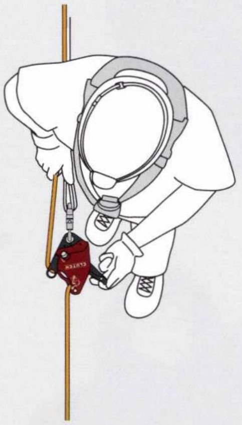
Personal Descent



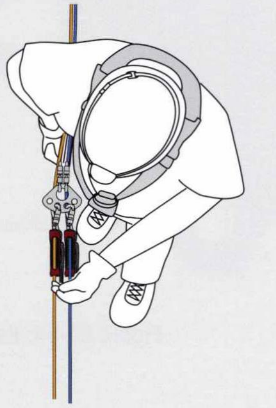
Belaying



Hauling Systems



Controlled Lower



Twin Tension Systems

MPD

The CMC MPD combines a change of direction pulley and mechanical advantage system ratchet into one component. The MPD also functions as a descent control device for a lowering system and as a rescue belay device. Since the MPD fulfills so many roles, its use in belays, lowering systems and raising systems will be covered in those chapters. For more information or to download the user's manual, visit cmcpro.com/manuals.

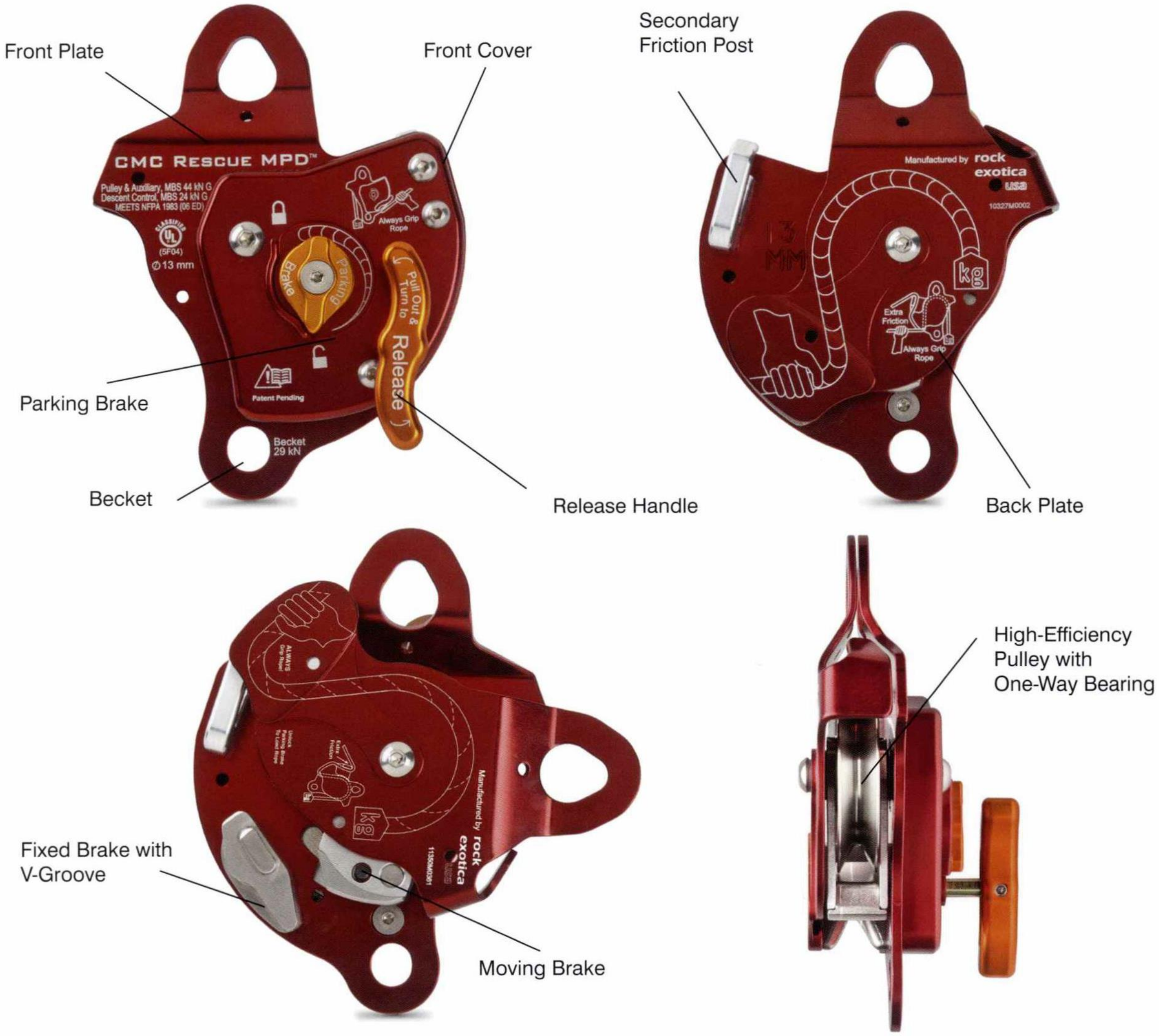

Front Plate
Front Cover
Secondary Friction Post
Parking Brake
Becket
Release Handle
Back Plate
High-Efficiency Pulley with One-Way Bearing
Fixed Brake with V-Groove
Moving Brake
CMC Rescue MPD™
Parking
Brake
Pull Out & Turn to Release
Always Grip Rope
Becket 29 kN
13 MM
Manufactured by rock exotica

Figure 06-14: Key Parts of the MPD

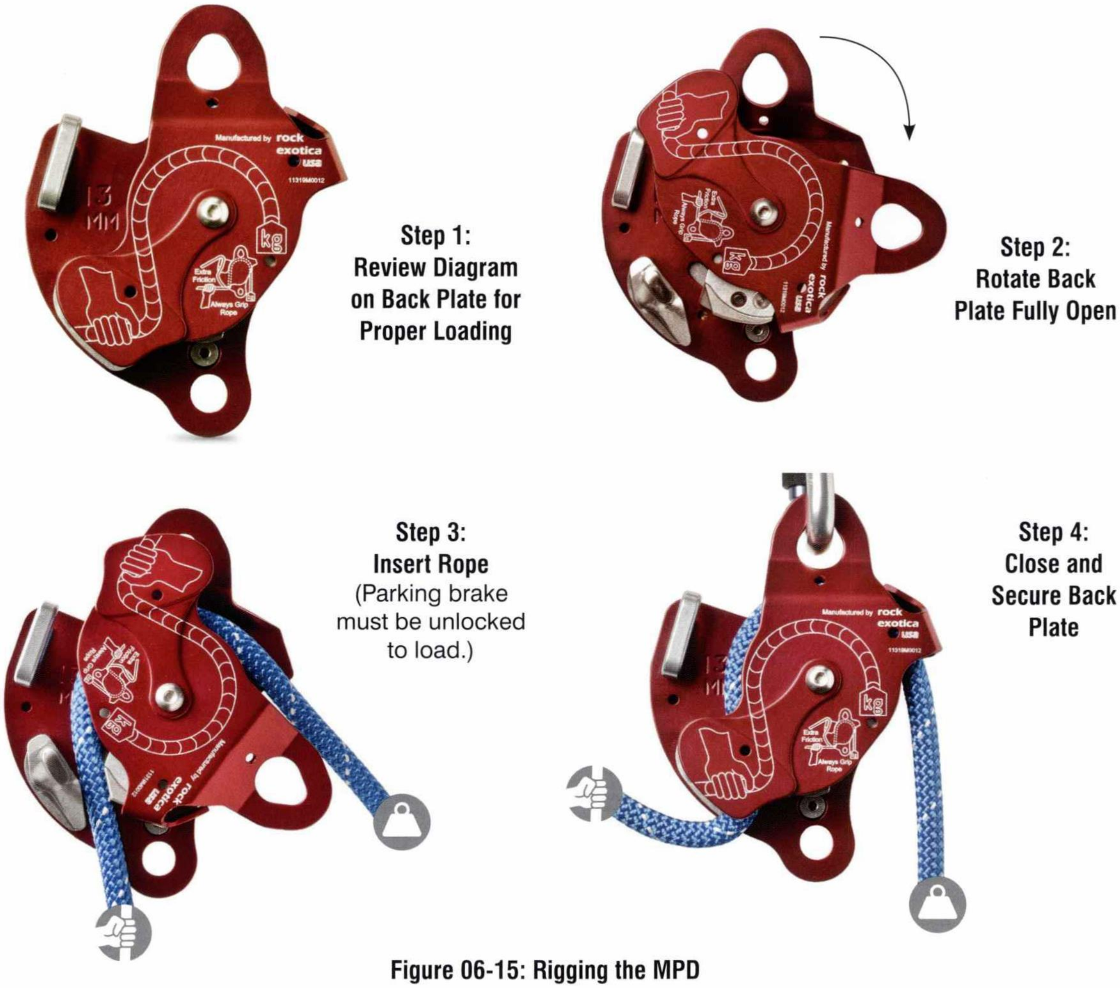
Rigging the MPD

The MPD is designed for use with static or low-stretch kernmantle life safety rope. Use only rope in good condition. To rig the MPD, first ensure that the parking brake is unlocked. Hold the MPD so that the back plate faces up. Take note of the laser-etched diagram showing the proper rope orientation, then open the MPD by rotating the back plate clockwise until there is space to insert the rope between the fixed and moving friction brakes.

Insert the rope with the running end between the friction brakes and wrap the rope around the pulley in a clockwise direction. The load end of the rope exits the pulley opposite the friction brakes.

Close the MPD by rotating the back plate completely counterclockwise and making sure that the rope properly enters and exits the MPD as shown in the diagram on the back plate. Attach an appropriate locking carabiner or screw link through both the front and back plates.

Always perform a safety check by disengaging the parking brake and giving a quick tug on the load end of the rope to ensure proper rigging prior to committing a live load over an edge. When rigged properly, the MPD will lock up. The MPD must be rigged correctly prior to use.



Step 1: Review Diagram on Back Plate for Proper Loading

Step 2: Rotate Back Plate Fully Open

Step 3: Insert Rope (Parking brake must be unlocked to load.)

Step 4: Close and Secure Back Plate

Figure 06-15: Rigging the MPD

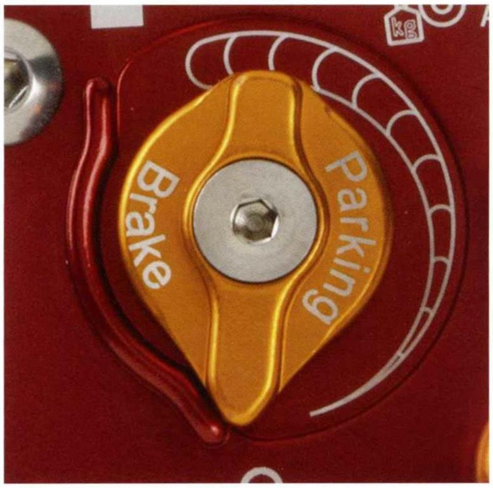


Figure 06-16: MPD Parking Brake

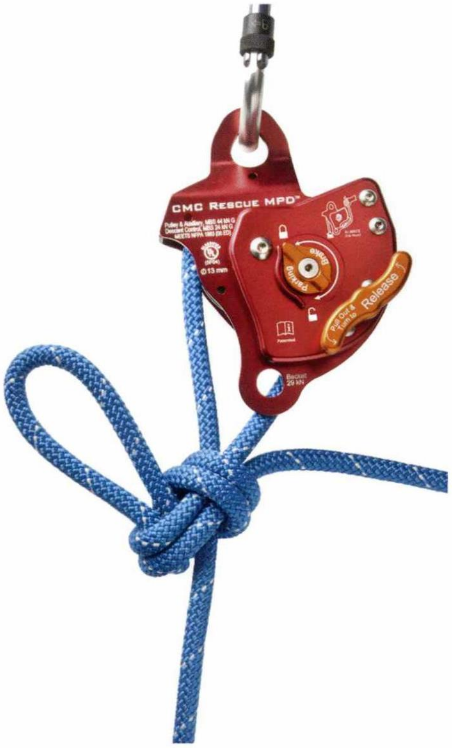


Figure 06-17: MPD Tied Off

Parking Brake

A unique feature of the MPD is the parking brake, which when engaged, prevents inadvertent letting out of the rope by manually engaging the braking mechanism. Engage the parking brake whenever you need to release your grip from the running end of the rope, except when the MPD is rigged as a ratchet or progress capture in a pulley system. For example, once the rigged MPD is clipped to the anchor, for safety, engage the parking brake until it is time to use the device.

To fully engage the parking brake when using oversize diameter rope, or if the rope is untensioned, icy, or saturated, it may first be necessary to pull out on the release handle and rotate it clockwise to further force the brake against the rope.

The parking brake is intended to be used to temporarily secure the MPD when it is necessary for the operator to release the grip on the running end of the rope. If the MPD is to be left unattended or if you need to release your grip on the running end of the rope for more than a short time, engage the parking brake and then secure the MPD by tying off the running end of the rope around the load end with an appropriate tie-off method (see Figure 06-16 and Figure 06-17).

Inspection and Care

Clean the MPD after each use to remove any dust or debris. If exposed to moisture, dry the MPD after use. Do not store the MPD where the equipment may be exposed to moist air, particularly where dissimilar metals are stored together.

The MPD is a robust unit, but as with other rope rescue equipment, it should be inspected after each use to ensure that damage did not occur. When inspecting, look for any damaged, dirty or sticking components, excessive wear or any other factor that may prevent proper functioning. If any damage is observed, the equipment should be retired from service.

The MPD must be inspected after an impact load has occurred. Inspect for any damage or deformation to the components. Evaluate the sheave for smooth operation of the bearing. The MPD should be immediately retired from service if any damage or indications of improper function are noted.

LOAD CELLS

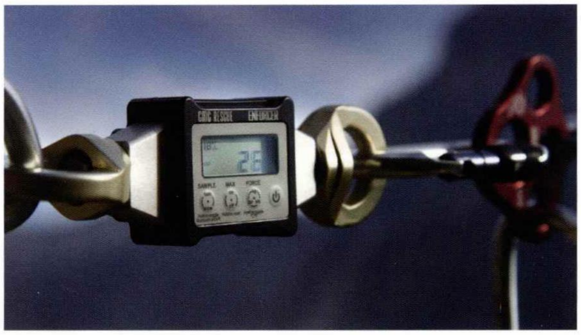


Figure 06-18: Load Cell used on a Highline

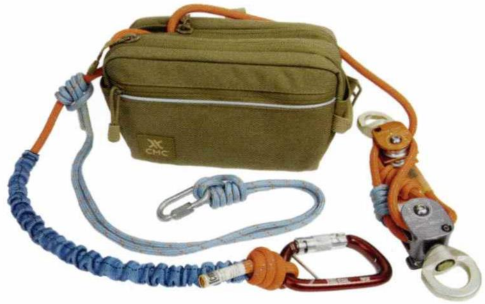
Estimating the forces on a rope rescue system can be difficult as the effects of friction and impulses from the haul team are not easy to see. A solution is to insert a load cell into the system. Load cells are very effective for providing visibility to the loads on highline systems.

The Enforcer is a compact load cell that fits easily into rope rescue systems. The swivels on the ends prevent torque on the unit. An app is available for remote monitoring of the system. CMC's version is classified NFPA general-use.

Use and Maintenance

For use, see the Quick Reference Card that comes with the Enforcer. For most load cells, clean and dry after each use to remove any dust, debris, and moisture. During use, carrying, and storage, keep the load cell away from acids, alkalis, and strong chemicals. Do not expose to flame or high temperatures. Do not store for long periods with the batteries installed.

AZTEK SYSTEMS



CMC AZTEK ProSeries System

Small jigger systems have been around for many years. Reed Thorne of Ropes That Rescue refined the concept several years ago and AZTEK kits are available from several manufacturers. While most of the rope and hardware components are the same, the design of the storage bag can make carrying and deploying the system more efficient.

On the mechanical advantage end of the rope are double pulleys that allow either a 4:1 or 5:1 system. When used as a piggy-back system such as for a knot pass, the mechanical advantage is a 5:1. When used for the tender on the stretcher, the AZTEK allows easy raising and lowering of the tender's position and the mechanical advantage is also a 5 to 1. Prusik hitches connect at either end to hold the system when you release it.

Pull the other end of the rope out of the bag, and with the carabiner, attach it to an anchor. The Prusik hitch on that end attaches to your harness for travel restraint fall protection.

When selecting an AZTEK system, look at all the Prusiks and attachment hardware offered. Sewn Prusik loops tend to be easier to work with than those with knots. A well designed bag should keep all of the rope inside, avoiding loops that could snag while walking, yet be easy to access either end of the rope. Some AZTEK kits have NFPA 1983 classification as life safety systems.

CMC's AZTEK ProSeries® LT has just the mechanical advantage system of the full AZTEK system. It works well for pick of rescues or for attaching the tender to the litter.

Use and Maintenance

AZTEKs are basically small rope rescue systems and operate as shown in later chapters. They should receive the maintenance as any other rope and hardware.

Load Release Strap

SEWN WEB EQUIPMENT

A *load release strap* is used whenever a ratchet or tandem Prusik belay is in the system. Like a mariner's knot or a load-releasing hitch, it allows a ratchet or Prusik hitch under constant tension to be transferred without having to remove the load from the system. While a single purpose device, the load release strap is easier to set up than a mariner's knot or a load-releasing hitch and has safety features that the hitches do not have.

The Pick-Off Strap and *Litter Strap* have adjustable lengths, which are used for connecting the rescuer to the subject or a litter tender to a litter. Typically sewn using $1^3/_4$ in web with an adjustable V-ring, they add efficiency when performing a pick-off style rescue or when tending a litter on a low angle evacuation. Both will be covered in more detail in later chapters.

Adjustable Litter Strap

Pick-Off Strap

Care and Maintenance

Inspection, care and storage for sewn web equipment is the same as for a rescue harness (see Chapter 7).

EQUIPMENT BAGS

Keeping the equipment organized and ready to go is just as important as having the right equipment in the first place. Over the years, equipment bags have evolved from backpacks and rope bags into specialty packs and modular systems. Some also incorporate the rope bag.

More than just storing equipment or making it easy to carry, the equipment bag should be used to organize the equipment so it is ready to deploy. For example, anchor equipment can go in one bag, the main line with its hardware in another and the belay line rope and equipment in a third. Or set up a bag so that the equipment inside can set up the main line or the belay. The goal is to end up at the rescue scene with all the needed gear in the first trip and then have the gear ready for quick deployment.

RETIRING EQUIPMENT

Determining when to retire expensive equipment can sometimes be difficult. When there are obvious cracks, tears or breaks, it is easy to decide to take it out of service. When it is not so obvious, no visible damage but a possible shock load or a slight irregularity in the core of a rope, it is best to remember that your life might be the next one to hang on that system. The only way to test the strength is to test the piece to destruction, which is just the same as retiring it. **When you are not sure, retire it.**

When it is retired, make sure it cannot accidentally end up back in a rescue system. A rope that ends up in the back of a truck to tie equipment down, or carabiners that end up holding keys on someone's belt loop, might be recognized as rescue equipment and returned to service. It has happened. When retiring equipment, cut it up, paint it black, anything that **PERMANENTLY** marks it as equipment no longer in service for rescue.

Note: Some organizations use black to indicate rope or equipment that has been designated for training. Other organizations use black to indicated retired equipment.

RigTech Pack™

Rope Bags

MPD Truck Cache™ Kit

Notes

PART 02

Rope Rescue Equipment

CHAPTER 07

Personal Equipment

TERMINAL LEARNING OBJECTIVE

The student will identify and select the proper personal safety equipment used during rope rescue operations.

ENABLING LEARNING OBJECTIVES

1. Describe the important features of various types of helmets used for rope rescues
2. Describe the difference between a Class II and Class III harness, harness inspection, and care
3. Describe the proper care and maintenance of a rescue harness
4. Describe the kinds of gloves used for rope rescue

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.2.2 | 5.2.3

Terrain, weather, type of call and call duration all have an influence on your selection of personal protective equipment (PPE). Department and government standards also dictate what you may or must wear. We do have a few suggestions and observations that we feel add to your safety and comfort during rope rescue responses. Since our situation may differ from yours, the particular equipment we use is not as important as the analysis used to select the best gear.

During this chapter we will often refer to levels of protection. As the level of exposure to harm increases, then the level of protection that your PPE provides should increase.

HELMETS

Wearing a helmet is an accepted safety practice in rescue work and it is particularly important for high angle situations. Besides falling debris or rocks, a team member above you may drop equipment. A steel carabiner dropped from several stories up will cause serious injury to an unprotected head. A helmet also reduces the risk of injury if the rescuer falls. Probably the most common cause of bumped heads occurs when two team members lean across the litter simultaneously.

The most common helmets used for rescue are either a sport climbing helmet or an industrial safety helmet. Function certainly influences the choice with light weight and a low profile the most common requirements. Look for a chin strap that is easy to adjust and will keep the helmet in place during a fall. This could be either a three-point or four-point chin strap. Industrial safety regulations may require rescuers to wear a helmet meeting a particular standard, usually ANSI Z89.1.

Fire service helmets provide the protection required in fire ground operations and this may be important if your rescues are taking place as part of a fire response. You should ask about the fall and impact protection that your helmet provides to determine its suitability for use in high angle rescues. You may find that the fire helmet is too heavy or too hot to wear as a rescue helmet. The size of a fire helmet can be a problem when working in tight spaces and may reduce visibility.

Rescue/Climbing Helmets

Rescue Helmet

Rescue/climbing helmets are lightweight and compact yet designed to protect from hazards during rescue operations. These helmets fit securely and have a low profile, which allows them to fit in the tight areas found in confined space, underground and some rock rescue situations. Certifications on these types of helmet may vary by model or manufacturer; such as EN 397, EN 12492, NFPA 1951, ANSI Z89.1, or CSA Z94.1.

Industrial Safety Helmets

Rescue helmets are now available with ANSI Z89.1 E rating for safety around electrical hazards on towers or other high voltage locations. Optional visors provide eye protection and some allow mounting of ear protection. Most helmets come with reflective stickers or offer them as an option.

Helmet visors keep the sun out of your eyes and can deflect falling debris away from the face. The Salamander Beak is a removable visor that attaches with a hook-and-loop connector to the front of the helmet. The CMC Sunbrero™ fits over the top of the helmet and provides 360° protection from the sun, but also works well for shedding rain. Both the Beak and the Sunbrero can be removed quickly if in the way and will flex if the helmet impacts a surface, reducing strain on the neck.

CMC Sunbrero™

HARNESSES

When selecting a harness, you first must decide what your role in the vertical environment will be and the level of protection you will need for that position. A harness can provide a quick clip-in point for a belay or emergency rappel, fall protection when working on a ladder or other exposed position, a work platform for the rescuer or a means of transporting the subject.

Belts

CMC Cobra-D Uniform Rappel Belt

The climber's swami belt and the firefighter's pompier belt are no longer considered to have acceptable levels of protection as work platforms or for fall arrest. If your weight has to be supported by a belt, the diaphragm and rib cage will compress, restricting your ability to breathe. In the case of a fall with a harness, the harness spreads the force over parts of the body, such as the buttocks and legs, which can better absorb an impact than the rib cage.

A rappel belt of the type that fits through your pant loops and has a metal connection point is worn as a uniform belt by a lot of rescuers. If you need a quick attachment point for a travel restraint, just clip into the D-ring. It will work for an emergency rappel, but you do not want to spend much time hanging in a rappel belt. Most people who wear these belts will do one or two rappels with the belt, so they know how it feels and then put on their rescue harness for the rest of the training session.

Improvised Harness

A quick diaper seat or hasty harness (also called a Swiss seat) can be used for an emergency rappel or as a seat for a subject if you do not have a harness available. The military used $^3/_8$ in (9.5 mm) rope, but one-inch webbing provides greater surface area against the body. Two-inch web is even better but has a bulky knot. For extra security a rescuer's hasty harness can be backed up to a rappel belt. For tying a hasty harness "Hasty Harness" on page 96.

Sit Harness (Class II)

For the rescuer in a rope rescue operation, we strongly recommend a sit harness (sometimes called a seat or pelvic harness) that is designed for rescue. Such a design transfers your weight to your legs and holds you in a sitting position for maximum comfort.

We recommend a minimum of three-inch-wide webbing or padding around the legs and waist. Climbing harnesses were often used for high angle rescue, but most of them only have a two-inch wide surface and do not provide the support for extended sitting. Remember that the rescuer—and this could be any member of the team—may be using the harness as their only support for relatively long periods of time. Leg straps reduce circulation to the legs and to the muscles underneath the harness. Only by increasing the width of the waist and leg straps can you minimize these effects.

For NFPA 1983 certification, a Class II harness must pass the drop test in a head down position as well as the head up. This verifies the unlikelihood of a rescuer falling out of a sit harness. In both rescue and recreational climbing, we are not aware of an instance where a person has fallen out of properly sized and adjusted sit harness

A low angle evacuation puts a lot of wear and tear on the body and a good rescue harness will help protect you. The lower back area usually feels the load when you are leaning back into the litter strap. The wider the belt around the waist, the more comfortable you are going to be.

We designed the ATOM Harness with a metal D-ring and found that it simplified clipping in, particularly when suspended in the harness. The D-ring also provided enough room to fit the carabiners for the main line, belay line, and a third-point of attachment.

Chest/Combo Harness

Wearing a chest harness and a sit harness provides the same stability as a full-body harness. Many rescuers like the flexibility of being able to wear just a sit harness when they want and then being able to have the upper body support when the situation warrants it.

A chest harness should only be used to keep the body upright and not as the sole means of support. The usual procedure is to connect the rope into the sit harness and then connect the carabiner at the chest harness around the rope. The exception is a chest harness that attaches to the sit harness. These will have lifting point D-rings in the back, front or both.

A chest harness that connects to the front waist D-ring allows the load from the sternal D-ring to be transferred to the waist D-ring, allowing a comfortable lift from the higher connection point. A sternal connecting point is often used for hoists since it keeps the user from tipping backward.

Often called a combo harness, this is a chest harness and sit harness that connect in both the back and the front, allowing a sternal lifting point and a rear connection for fall protection. Both the sternal and dorsal connectors transfer the weight to the pelvis like a full-body harness. NFPA 1983 allows a combo harness to be certified as a full-body (Class III) harness for fire service operations. Because the two components can be separated, ANSI Z359.11 does not allow a combo harness to be certified as a general industry personal fall arrest system.

Sit or Pelvic Harness

Full-Body Harness (Class III)

A full-body harness is generally heavier than a sit harness but usually offers more points of connection. While today's certified sit harnesses are tested for inverted falls, the shoulder straps on a full-body harness decrease the likelihood that an inverted user might fall out. The upper section of the harness can also be used to place pockets for a radio or other equipment. In NFPA 1983, a full-body harness is referred to as a *Class III* harness.

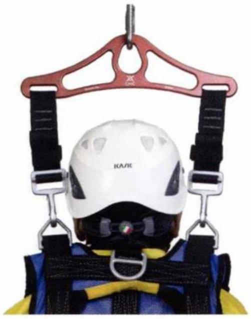
Chest/Combo Harness

While they may look similar, a full-body rescue harness differs from a harness intended for fall protection. Like recreational climbing harnesses, industrial fall arrest harnesses were designed to catch a person's fall. They were not designed to be sat in while working. The rescue harness may have fall arrest attachment points, but it also has the front waist connection point to hold you in a sitting position for rappels, litter tending or working on rope.

The dorsal attachment point for the fall arrest system is located on the upper back near the shoulder blades. This provides the best position to arrest a fall into open space and support the user until rescued, but a very awkward position for self-rescue. To meet the maximum allowable impact force, most fall protection systems include a shock absorber.

The sternal connection point provides an added level of safety when climbing a ladder or working on a building or cliff where a dorsal connection point would rotate the wearer's head into the structure during a fall. It also leaves the wearer in a sitting position, better able to effect a self-rescue. ANSI Z359.11 permits the use of a sternal connection point if a competent

Full-Body Harnesses



Spreader Bar

person determines a dorsal attachment is not appropriate and there is no chance of the fall being other than feet first.

NFPA 1983 designates attachment points as either ***load bearing*** or ***positioning***. Load-bearing attachment points meet the performance requirements for fall protection. Positioning attachment points are strong enough to support the wearer while working at height but are not intended to take a high impact fall. (This applies to sit harnesses as well as full-body harnesses under the NFPA standard.)

One type of positioning attachment point is at the shoulders. With the use of a spreader bar to clear the head, the wearer can be suspended in a straight bodily position for vertical movement through a very narrow opening. There is a difference of opinion on the necessity of the shoulder lift as many confined space rescuers prefer to lift from the dorsal or sternal point and feel the shoulder is not necessary. The mid-dorsal connection point tends to provide a straight lift even when the occupant is wearing a breathing apparatus.

Many manufacturers build task-specific full-body harnesses that have features unique to the type of rescue: water rescue harnesses of polyester web and stainless steel hardware, tactical harnesses that are lightweight and quiet or harnesses that have places for attaching flotation or HEED bottles for overwater flights.

Selecting a Harness

When selecting a harness, look for one that fits your body size and shape the best. If possible, try to hang in several different models. Ask instructors or rope rescue technicians about their harness. The waist belt should fit above your hips for the most security, particularly with a sit harness. Buckles should not be digging into any bones, straps should not pinch and the leg straps should fit comfortably between the legs.

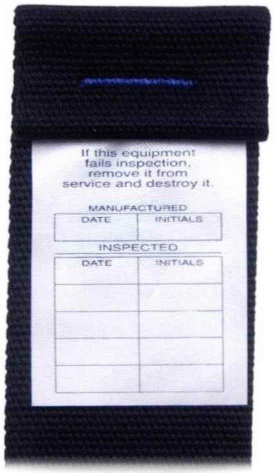
Inspection and Care

Any harness, whether made of leather or nylon, riveted or sewn, will wear with use. It is your responsibility to inspect the harness that you will be wearing. If you own the harness, inspect it regularly. If you use a harness that is kept with the rest of the rescue gear, inspect it before you put it on for a rescue or training. Read (and keep) the manufacturer's instructions for inspection. Keep the harness away from acids, alkalis, exhaust emissions, rust and strong chemicals.

When inspecting a harness, look for damage to the webbing or thread; cuts, frayed areas, or discoloration. If the harness has one, check the fall arrest indicator. If any of the above is noted, or the harness has been subjected to a shock load or abuse other than normal use, retire it.

Your harness can be washed in cold water with a mild detergent. A washing machine cleans better than soaking in a tub, but make sure the buckles do not damage the washer. Dry out of direct sunlight. A harness can be decontaminated using department procedures.

Why not keep a web gear and harness log like you do a rope log? If the rescuers use equipment that is on the rescue truck, a harness log could be just as important a part of safety and documentation as a rope log. See NFPA 1858 ***Standard on Selection, Care, and Maintenance of Life Safety Rope and Equipment for Emergency Services*** for considerations for when to retire a rescue harness.


If this equipment fails inspection, remove it from service and destroy it.
MANUFACTURED
DATE
INITIALS
INSPECTED
DATE
INITIALS

Inspection Tag

GLOVES

Whenever rope is moving through your hands, you must wear gloves. They protect your hands from the rope as well as the other hazards found in a rescue situation. While any leather glove will work, gloves designed for rope rescue have several useful features.

When selecting gloves, you will have to compromise between protection and feel. Heavy-duty gloves with thick leather and padding protect the hands better but reduce dexterity. You may have to remove the glove to work with knots or even hardware. A thinner glove allows more sensitivity but will not protect the hands as well. Choosing supple leather, such as deerskin or goatskin, may allow a tighter fit for better dexterity than a bulky loose fitting glove. You need to decide for your situation the best balance between protecting the hands and being able to work with the hands. In some cases, you may find the need to carry more than one type of glove.

What differentiates a rappel glove from a hardware store model is usually the double palm. This puts an extra layer of leather at the location of the greatest heat buildup during use and the point of most wear. On some brands, the double layer of material can extend up the fingers, onto the thumb or even on the knuckles of the back of the hand. Depending on the way you hold the rope, the web between the thumb and forefinger can also be a point of high wear. A good rappel glove design will have an extra layer of material at this point, too.

Using a variety of gloves over the years, we found that the gloves would come apart at the seams before the leather wore out. This resulted from the gloves getting wet and the torque placed on the gloves during rappels. We began using Kevlar thread in our gloves, and the seams now outlast the leather.

BOOTS

Boots protect and support your feet and ankles and provide traction on poor surfaces. They also protect you from the environment in rain, snow and cold. For rough terrain rescue, we prefer a moderately heavy mountaineering boot. The stiffness and narrow sole helps in climbing situations and the foot is well protected when carrying heavy loads, such as a litter. A stiff toe helps protect the foot when kicking steps in scree or snow slopes.

For confined space, industrial and urban responses, a lighter duty boot should provide adequate performance. Look for good foot and ankle support. The boot should fit well, so the foot does not slide around inside. The sole should provide good traction. For some industrial rescue applications, steel toe boots may be required.

LIGHTING

A rescue team member must be able to operate in darkness as well as light. Your primary light should be a headlamp to keep your hands free to work and which will make travel easier. Headlamps have become more powerful over the years and most models allow the brightness to be adjusted, balancing your ability to see while maximizing battery running time. When traveling, a lower light output can be used, thus increasing the battery life. Maximum brightness can then be used only when you need to have the additional light. Close quarters, such as those found in caves and confined spaces, require less brightness because of the reflected light from the nearby surfaces.

A backup light should always be carried—since failure of your only light source can effectively eliminate you as part of the rescue team, and depending on the circumstances, you could become the next subject. Spare batteries (and for incandescent lights, spare bulbs) should be carried for all your lights. If your rescues can be lighted from vehicles or with portable lights, your headlamp can be your backup.

Chemical light sticks should not be depended upon as a primary backup light, but you should still carry a few. They are safe around flammable materials, such as brush or chemicals. They are excellent for marking your pack or gear bag, so you can find it or so others can locate you. Use light sticks to mark key egress points on a trail or walkway, so you can find your way back out.

Personal size strobe lights have been proving popular. We have used them at night to locate field teams when visibility has been limited by clouds and rain. They can make the position of a team going down through brush on a car-over really stand out. Because of the dense smoke in California wildfires, rescue teams also use strobes to mark the trail, even during the daytime.

Confined space regulations may require that you have a light that is certified as intrinsically safe for the atmosphere you will be in. Many lights are advertised as intrinsically safe, when in fact they are only approved for a limited number of atmospheres. Look to see what your particular requirements are and then check with the manufacturer for the current approvals.

CUTTING TOOLS

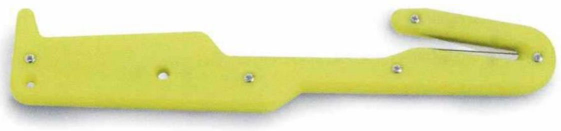
Two axioms we learned years ago:

Anyone working around rope should have a knife.

It does not take very much for a sharp edge to cut a loaded rope.

The important thing is to be able to cut the right rope while making sure you do not accidentally cut the wrong one, meaning any load-bearing rope, particularly if you are the load. A rope under load cuts much easier than a rope with no load on it.

For years we have recommended carrying the large utility scissors (sometimes called trauma shears). These scissors are safer around loaded ropes than a knife but will cut a loaded 7/16-in. (11.1 mm) rope in a single snip. They are also lightweight, have no sharp point or edges if they are dropped, can be clipped into a carabiner and can be used as medical scissors. Hook knives, such as the guides safety knife, also provide the ability to cut safely while protecting the other lines in the vicinity.



Hook or Safety Knife

Utility Scissors

FOOD/HYDRATION

Everybody knows that a mountain rescue or a cave rescue takes a long time, but even a vehicle-over-the-side or other urban rope rescue situation can easily take several hours. Good performance equals safety and this requires recharging your hard working body. We have seen rescuers start to burn out due to low blood sugar or dehydration, so access to fluids and simple snacks will help.

Water, particularly on a hot day, is often the least likely to be carried but is what may be needed the most. Your ability to function can drop quickly as you dehydrate and start to feel the effects of the environment. There are an amazing number of electrolyte replacement products on the market. Pick one that meets your needs. Hydration packs make getting a drink easier, so you stay better hydrated.

During a long rescue, something to eat will help keep your energy level up. On cold days, replenishing carbohydrates will also help keep you warm. Try trail snacks or the high-energy bars that you can carry in a pocket of your pack or jacket. Whenever there is a break in your part of the activity, then you can take the opportunity to take a few bites.

SAFETY TIPS

Inspect your equipment on a regular basis. Look at it carefully before you put it into service. When repacking your kit after a rescue or after washing your equipment, inspect it again. It is your life support equipment, so satisfy yourself that everything is the way you want it.

There are a couple of personal equipment items that we nearly always carry on a rescue or training. One is the pair of large utility scissors that we mentioned above. Next would be a Prusik sling and a carabiner. They can be used for a self-belay on a rappel, an adjustable tie-in to a safety line or as a short runner. The Prusik can be stuck in a pocket or worn around the neck under your jacket. The carabiner can go in a pocket or you can clip it to your rappel belt.

Extra Prusiks are a good idea. They tend to wear out and spares can be used for a variety of tasks. Include an extra long one, about 10 feet in length is a good size. Use it as a Prusik and foot loop for climbing, a long safety Prusik or to tie a load-releasing hitch.

RETIRING PERSONAL EQUIPMENT

Retirement of personal equipment is the same as for team equipment "Retiring Equipment" on page 69 and page 77. See also NFPA 1858 ***Standard on Selection, Care, and Maintenance of Life Safety Rope and Equipment for Emergency Services.***

PART
03
Basic Skills

CHAPTER
08
Knots

LEGEND: Anchor Grip Load

TERMINAL LEARNING OBJECTIVE

The student will identify and properly tie knots, bends and hitches used in rope rescue systems.

ENABLING LEARNING OBJECTIVES

1. Define the qualities of a rescue knot
2. Define the parts of a rescue knot
3. Demonstrate how to properly tie the required knots

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.2.4

"Little is known about the mechanics of knots, and the friction itself is still a scientific mystery. Under the circumstances, it behooves the layman to speak skeptically rather than dogmatically about the way knots behave the way they do." [1]

A rescue team should rely on a limited selection of knots that do their jobs well. By standardizing the knots used, there are fewer knots for team members to learn. During a rescue, checking the knots is much easier since a particular knot will be expected at a given position. These advantages become important during the stress and confusion that are always present during an actual rescue.

The knots that are included in this manual were picked because of their strength, simplicity and ease of untying after having been loaded. Most have been around a long time and are known by several different names. In this manual, we have used the names most familiar to the rescue community. Again, standardization of knot names also helps to eliminate confusion.

Knot tying is a skill that can be practiced alone. A team member should be able to tie each of their team's knots. An inability to do so may be a warning of a lack of desire to develop the basic skills necessary to be a safe team member. The middle of a rescue is not the time to try to figure out what knot to use, how to tie it or to discover that a team member has neglected to learn the basics.

Knot Efficiency in 1/2" Kernmantle Life Safety Rope

	100% Nylon Sheath/Core	100% Polyester Sheath/Core
Alpine Butterfly - Rope pulled end to end	69%	60%
Alpine Butterfly - Rope pulled loop to end	80%	61%
Bowline	71%	58%
Double Loop Figure 8	77%	67%
Double Fisherman's Bend	76%	80%
Figure 8 Bend	60%	66%
Figure 8 on a Bight	78%	70%
Poacher's Knot	78%	69%
In-Line Figure 8 - Rope pulled end to end	54%	49%
In-Line Figure 8 - Rope pulled loop to end	77%	63%

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[1] Day, Cyrus L. *The Art of Knotting and Splicing*, 4th edition. Annapolis, MD: Naval Institute Press; 1986.

WHAT MAKES A GOOD KNOT?

The tensile strength of a rope is derived from a test that pulls a straight rope with no bends until it breaks. Bends in a rope weaken the rope and the sharper the bend, the more strength is lost. Since a knot is a series of bends, we pick knots that have the largest possible bends while still being manageable. This results in the minimum loss of strength possible.

Knot strength is really the strength that remains in the rope after tying the knot. Samples of the rope are connected to bollards that hold the ends without reducing the strength of the rope. Control samples without a knot are tested to determine the rope's tensile strength. Then samples with the particular knot are tested. The percent difference between the straight rope and the knotted rope is the ***knot efficiency***. For example, a rope with a 10 kN tensile strength that breaks at 8 kN with the knot in it means that this knot has an 80% efficiency rating.

The knot efficiency in the accompanying chart, and included with some of the knot illustrations, is based on testing that CMC has performed over the years. A variety of factors affect the results, including but not limited to fiber, diameter, core construction, sheath construction, rate of pull of the test, and to a certain degree, the conditions in the test lab.

It is important to use knots that are similar to tie and then easy to inspect to assure that they are tied correctly. Many of the knots used for tying rescue rope are from the Figure 8 family of knots. They are simple to tie and look alike when tied correctly. Knots in webbing are based on the overhand family of knots for the same reason.

Neatness counts when tying a knot. Making the rope run smoothly without any extra bends or twists is called dressing the knot. It makes the knot stronger and easier to check.

A good rescue knot should be easy to untie after being subjected to a rescue load. To untie a knot, create some movement that generates slack somewhere in the knot to create some more movement. Try pushing parallel strands opposite directions or bending a loop further. Sometimes twisting or rolling the knot between your hands will help. In an emergency, if you cannot untie a knot, you should be equipped to safely cut the rope.

SAFETY KNOTS

After careful consideration, we no longer emphasize the need to add a safety knot to some of the knots shown in this manual. One of the criteria for the knots selected is that they are inherently tight. These knots tighten when loaded and do not come loose when the tension of the load is removed.

CMC PRO TIP

A quick way to verify that you left enough tail coming out of a knot is to use your hand. For knots in webbing, the tail should be as long as the width of your palm. For knots in rope, the tail should be the length of the hand from the wrist to fingertips.

We do continue to stress the importance of a safety check that includes being sure that all of the knots in the system are tied correctly and that proper knot tying technique includes pulling the knot snug before it is loaded. There should be at least 6 in (15 cm) of tail remaining from knots tied with rope and 3 in (8 cm) remaining from knots tied with webbing after the knots are pulled tight.

KNOT TERMINOLOGY

Bight – Formed when the rope is doubled back but does not cross.

Loop – Formed when the rope doubles back and crosses itself.

Working End – The end of the rope used to tie the knot.

Standing Part – The part of the rope attached to something, usually an anchor. The fixed part as opposed to the working end.

Knot – Generic term that is also specifically used for any knot that is not a hitch or bend.

Bend – A knot that connects the ends of two ropes or lengths of webbing together.

Hitch – A knot that attaches a rope to another object, including another rope if the host rope is not part of the knot.

Tail – The free end of rope or web extending out of the knot.

Round Turn – A complete turn of the rope circling a post.

Dressing a Knot – Making sure that the rope strands are smooth within the knot.

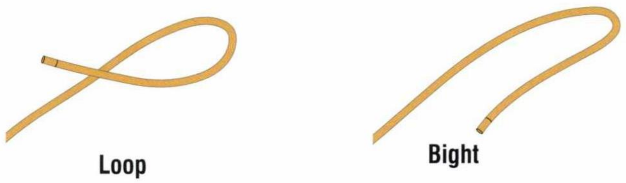


Figure 08-1: Example of Bight and Loop

THE FOUR KEY KNOTS FOR RESCUE

There are four key knots that are used frequently during rescue incidents. Each has several variations or alternatives.

Water Knot

Round Turn and Two Half Hitches

Prusik Hitch

Figure 8 on a Bight

Overhand Knot

The basis for the Water Knot and other knots. Can be used as a safety knot in webbing or rope.

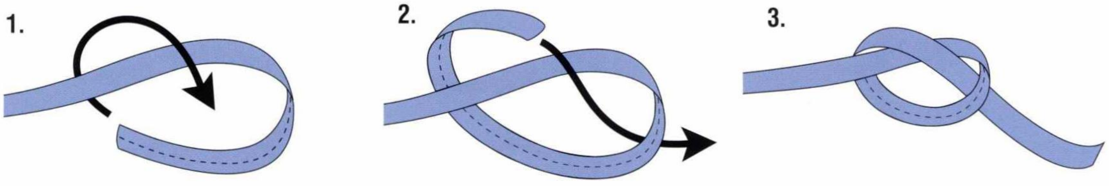


Figure 08-2: Overhand Knot

Water Knot (or Ring Bend)

Sometimes called an overhand bend or ring bend, the water knot connects two ends of webbing together. Knot efficiency - 64%.

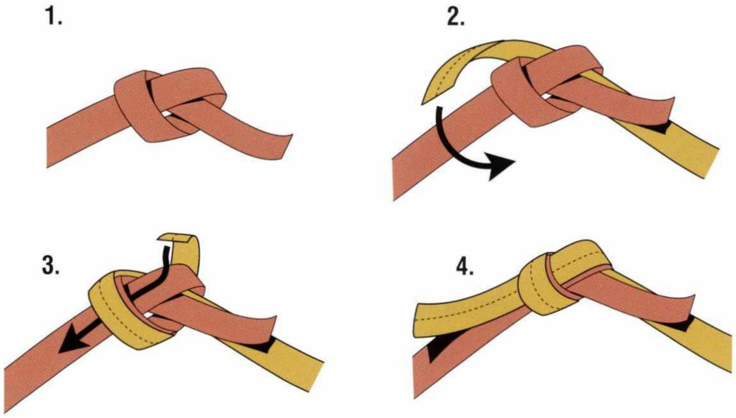


Figure 08-3: Water Knot

Overhand Loop

Used to make a loop in the end of a length of webbing.

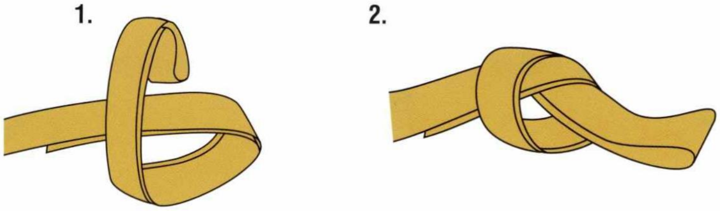


Figure 08-4: Overhand Loop

Round Turn and Two Half-Hitches

Use the round turn and two half hitches to connect webbing to the rail on a litter when tying in a patient. The load goes primarily on the round turn. When tied, the webbing can be pulled tight and then the knot finished.

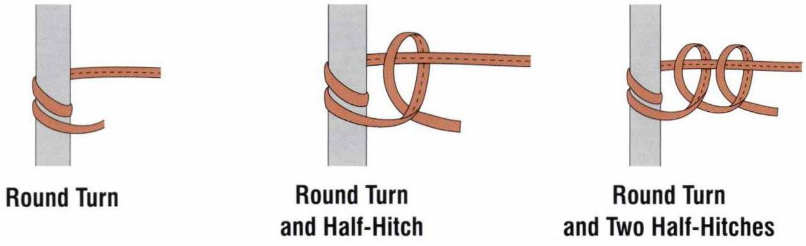


Figure 08-5: Round Turn and Two Half-Hitches

Clove Hitch

Often used in place of a round turn and two half hitches. Tie off by continuing to wrap the web around the railing and then an overhand knot around the standing end.

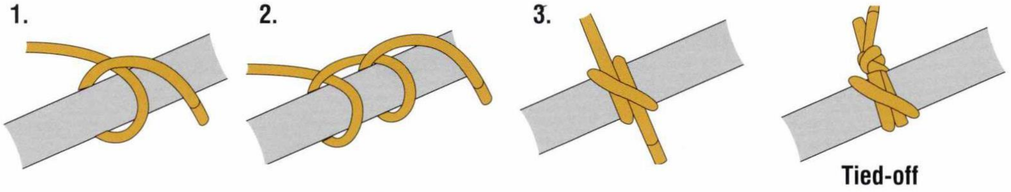


Figure 08-6: Clove Hitch

Prusik Hitch

The Prusik hitch is the preferred gripping or friction knot. It is easy to remember how to tie, is compact, and grips the rope when pulled in either direction. Tie by placing a loop near the rope then passing the sewn or tied end around the rope and through the loop. Dress the cords from the center out to the bridge on the outside. To release, start by pushing on the bridge to loosen the hitch.

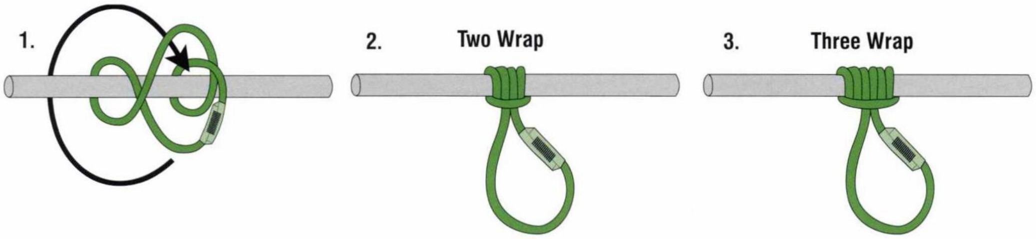


Figure 08-7: Prusik Hitch

Double Fisherman's Bend

This is the knot used to tie the loop of cord for making a Prusik hitch. It is a very secure self-locking knot that can be difficult to untie when loaded. When used to tie two ropes together, it makes a very compact knot that will fit through a knot pass pulley easier than the Figure 8 bend. When tied, there should be a least 6 in (15 cm) coming out of the knot; *except* when tying a loop for a Prusik hitch. Then 2 in (5 cm) will keep the tails from interfering with the hitch.

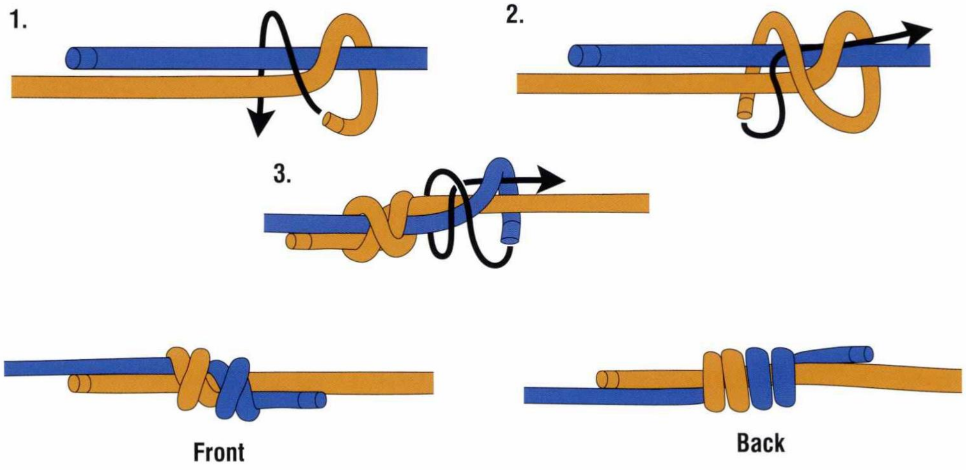


Figure 08-8: Double Fisherman's Bend

Poacher's Knot

Essentially a loop made by tying half of a double fisherman's bend, the poacher's knot is a very compact knot that pulls tight and grips the object it is tied to. CMC uses it to connect the end of a mechanical advantage system to the becket on a pulley or to connect an escape line to a carabiner hook. (We learned it as Scaffold Knot but found later, Poacher's was the correct name. The Scaffold Knot has three wraps).

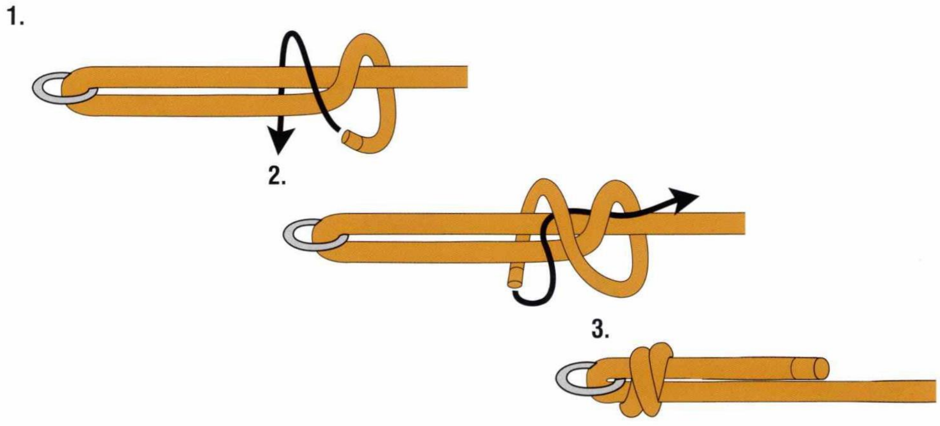


Figure 08-9: Poacher's Knot

FIGURE 8 KNOTS

Figure 8

This is the basic knot for the Figure 8 family and also a good stopper knot for the end of a rope.

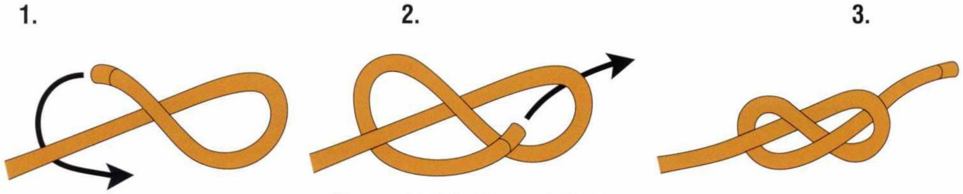


Figure 08-10: Figure 8 Knot

Figure 8 on a Bight

We use the Figure 8 family of knots for making loops to anchor the end of the rope and for connecting rescue rope together. The Figure 8 on a bight creates a loop for connecting a carabiner to the rope.

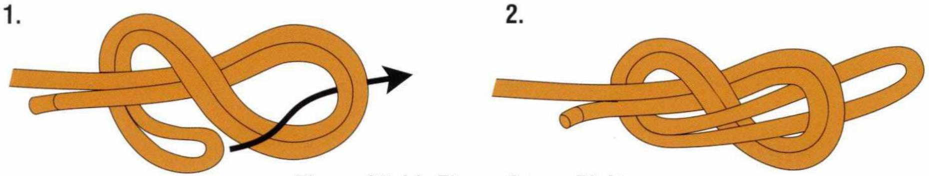


Figure 08-11: Figure 8 on a Bight

Figure 8 Follow-Through Loop

This is the same knot as the Figure 8 on a bight, but tied around an object to set up an anchor. It is also the knot climbers use to tie into their harness.

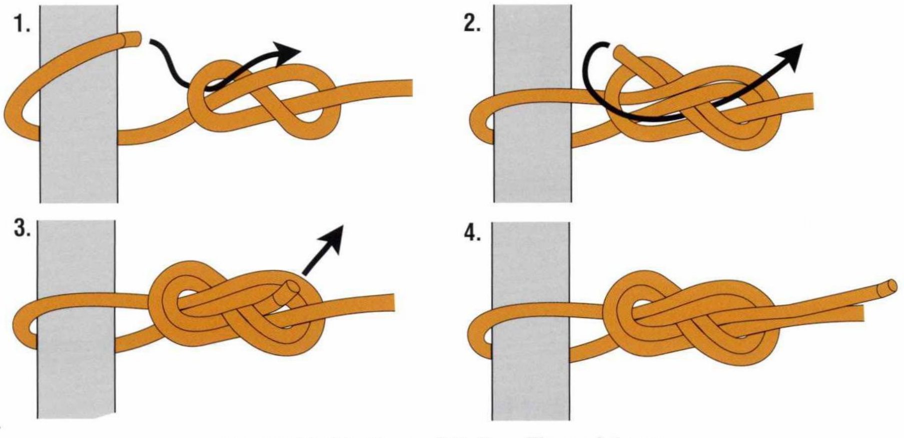


Figure 08-12: Figure 8 Follow-Through Loop

Figure 8 Bend (Figure 8 Follow-Through)

The Figure 8 bend is used to tie two ropes together. It is a self-locking knot and the large bends make it easier to untie after the rope has been loaded than other knots. Our recent testing of this knot showed a much lower efficiency than earlier tests.

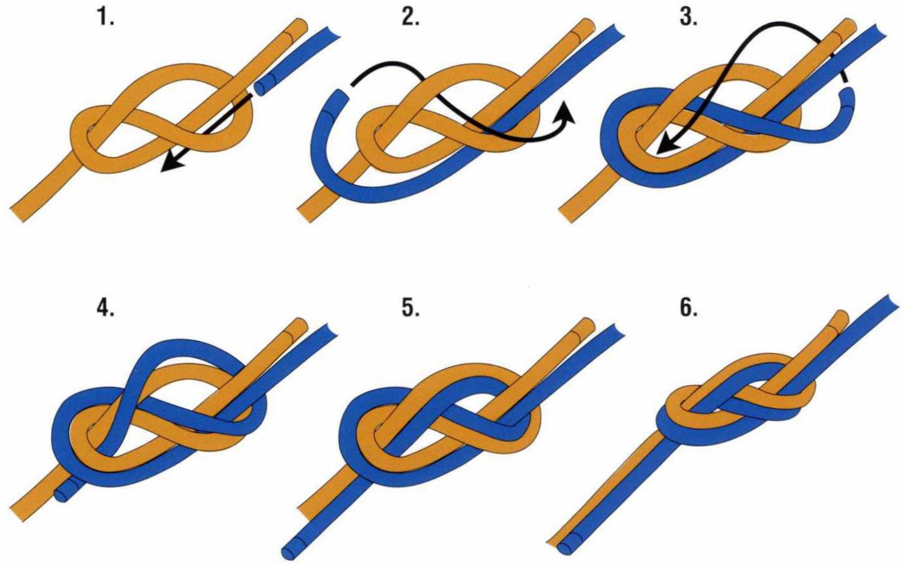


Figure 08-13: Figure 8 Bend

Double-Loop Figure 8

Used when you want two loops in the end of the rope.

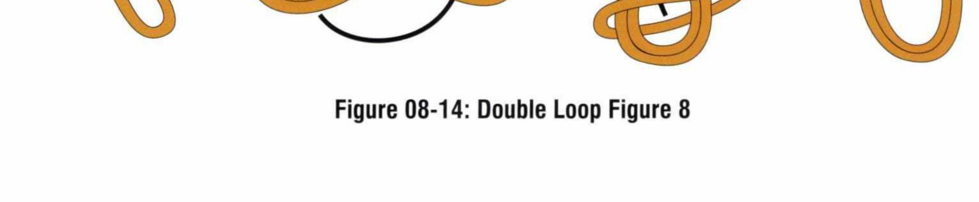


Figure 08-14: Double Loop Figure 8

OTHER KNOTS

Tensionless Hitch

A very quick anchor that eliminates the knot at the anchor point, if you have enough wraps around a large, not-too-smooth surface. Knot efficiency - 100% (if the diameter of the anchor is at least 4 in (10 cm)).

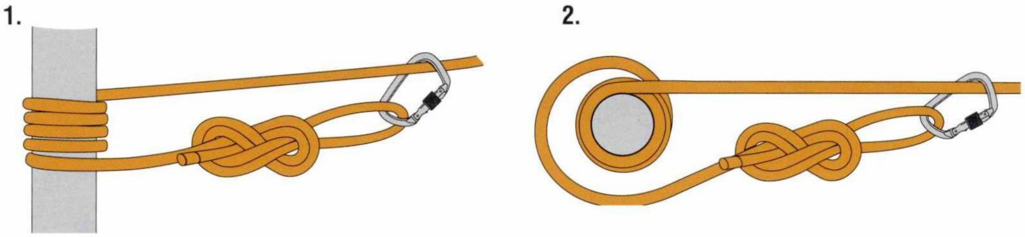


Figure 08-15: Tensionless Hitch

High-Strength Tie-Off

This is the improved version of the tensionless hitch used in the CMC School classes. After wrapping, add an overhand knot around the standing line. This adds a small amount of tension, which causes the wraps to grab a little better—very useful if the surface is smooth. Knot efficiency - 100% (if the diameter of the anchor is at least 4 in (10 cm)).

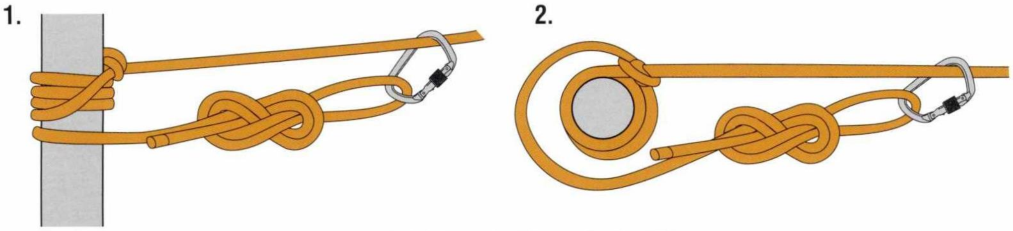


Figure 08-16: High-Strength Tie-Off

Munter Hitch

A sliding friction knot that can be used for a rappel or belaying a single-person load.

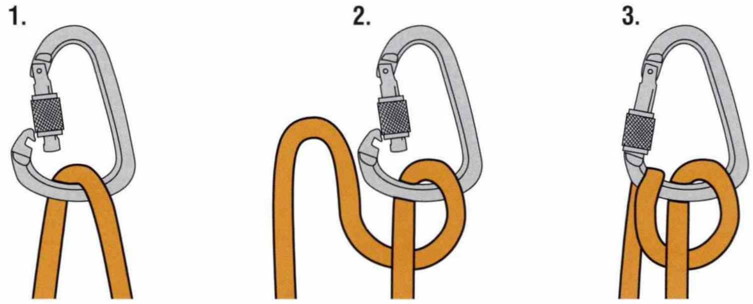


Figure 08-17: Munter Hitch

Mule Tie-Off

Use the Mule Tie-Off to secure the Munter Hitch when stopping a rappel or locking off a belay. The Mule Tie-Off can be tied and un-tied while the Munter Hitch is under load.

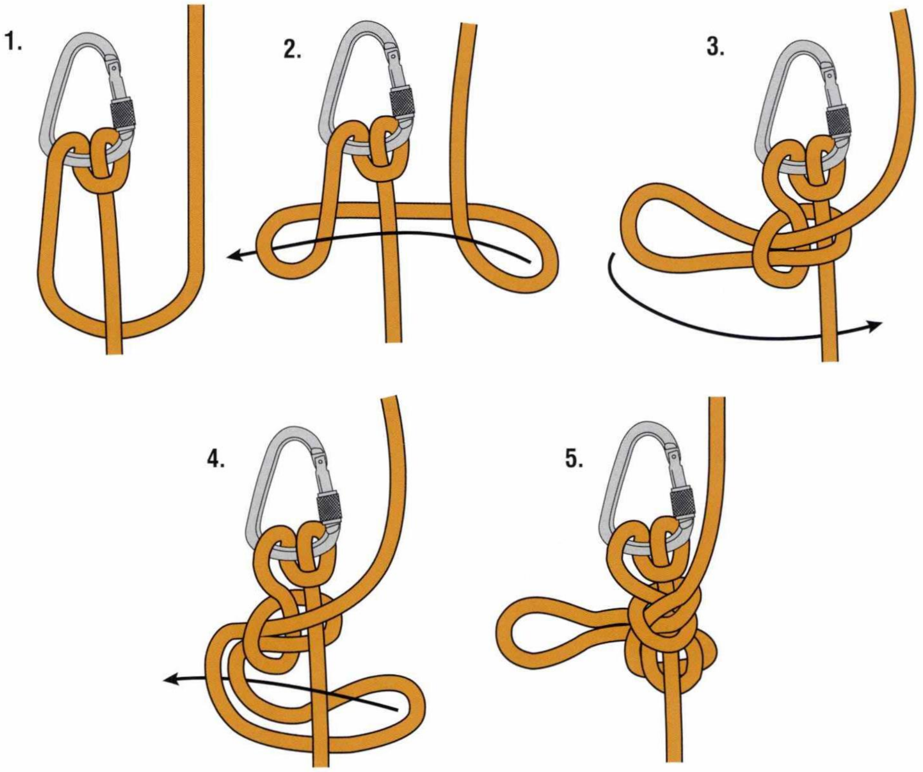


Figure 08-18: Munter Hitch with Mule Tie-Off

Alpine Butterfly

A popular knot for making a loop in the middle of the rope. Not quite as strong a loop as the Figure 8 but reduces the rope strength slightly less when the ends of the rope are pulled. Two methods of tying the butterfly are common.

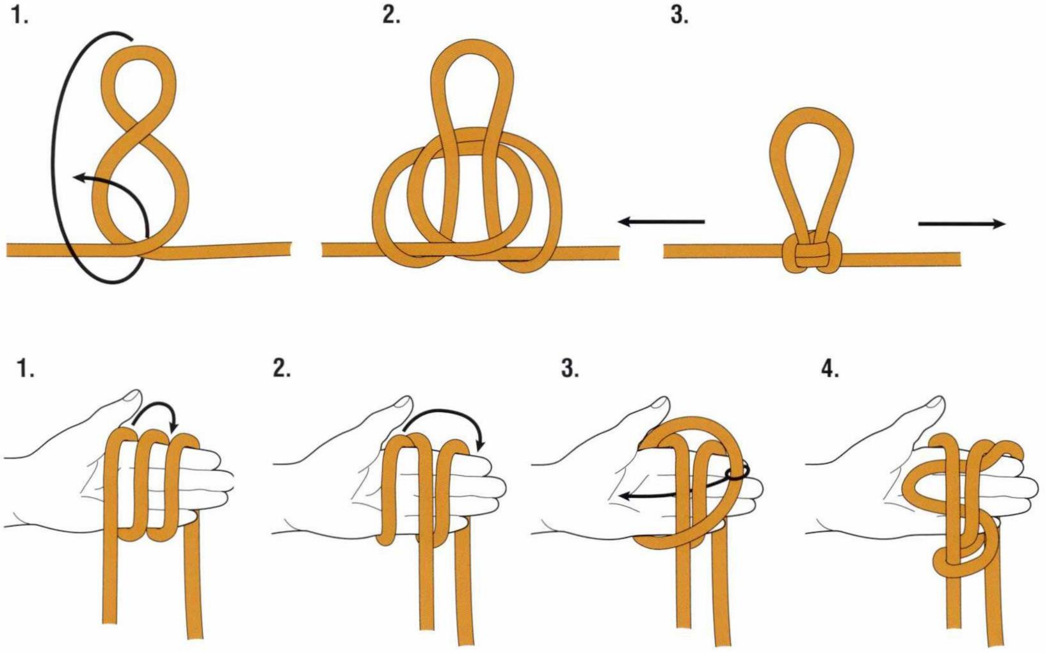


Figure 08-19: Alpine Butterfly Knot

Bowline

We have never been fans of the bowline but it does have its place in certain applications. Because it is susceptible to toppling if not under constant load, it has been the cause of several climbing accidents. However, it is very useful when tying a rope around an anchor point. Unlike the Figure 8 follow-through, there is no need to guess where to put the first half of the knot. The bowline must always have a safety knot.

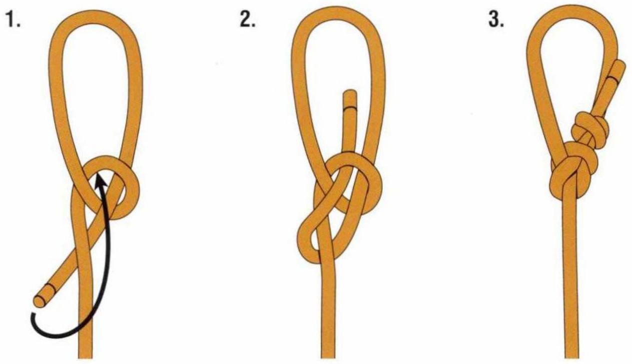


Figure 08-20: Bowline

Long Tail Bowline

Use the Long Tail Bowline to extend the two ropes from the system to provide a tender line and belay, two tender lines, or if a separate tender line is used, then a belay for one tender or two. A safety knot is not required due to the long extension of the tail coming out of the knot.

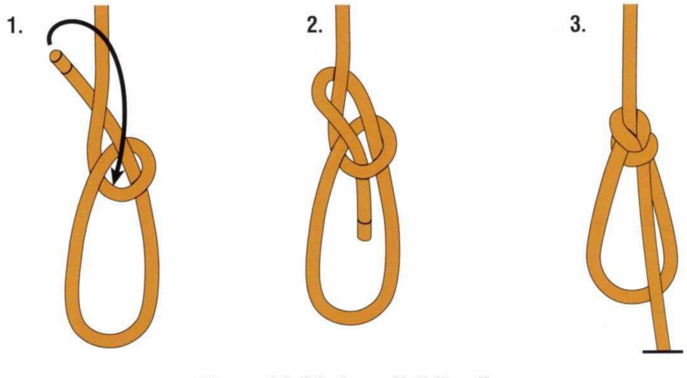


Figure 08-21: Long Tail Bowline

Portuguese Bowline

To attach a system rope directly to a vertically oriented litter, the Portuguese Bowline captures several structural elements. This is also a good way to attach a tag line to the end or side of the litter. While the original name is Portuguese bowline, it is also known as a French bowline and also by the descriptive name, bowline on a coil.

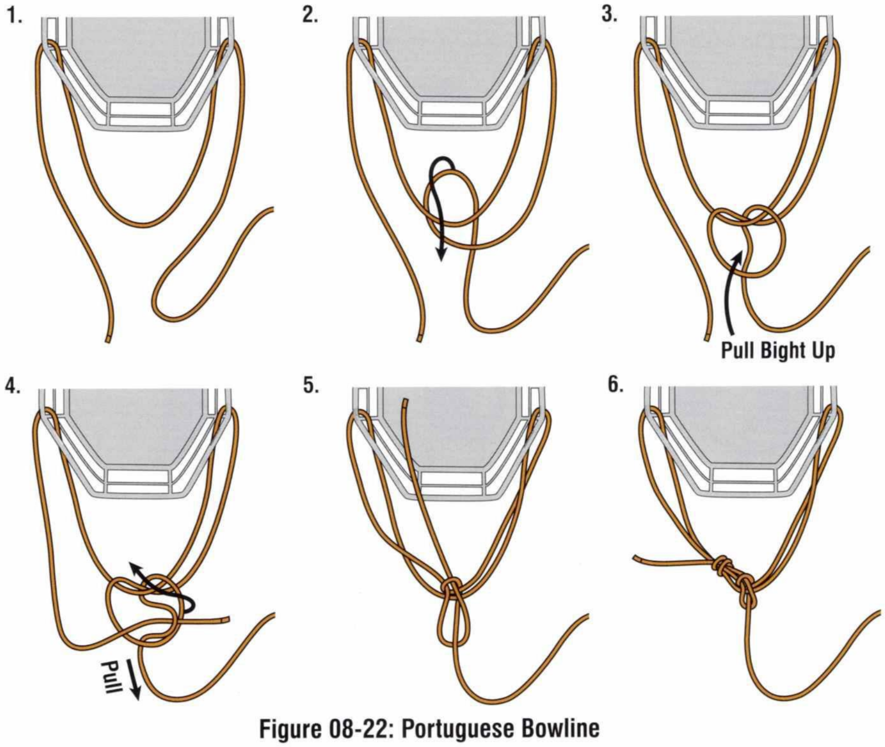


Figure 08-22: Portuguese Bowline

Trucker's Hitch

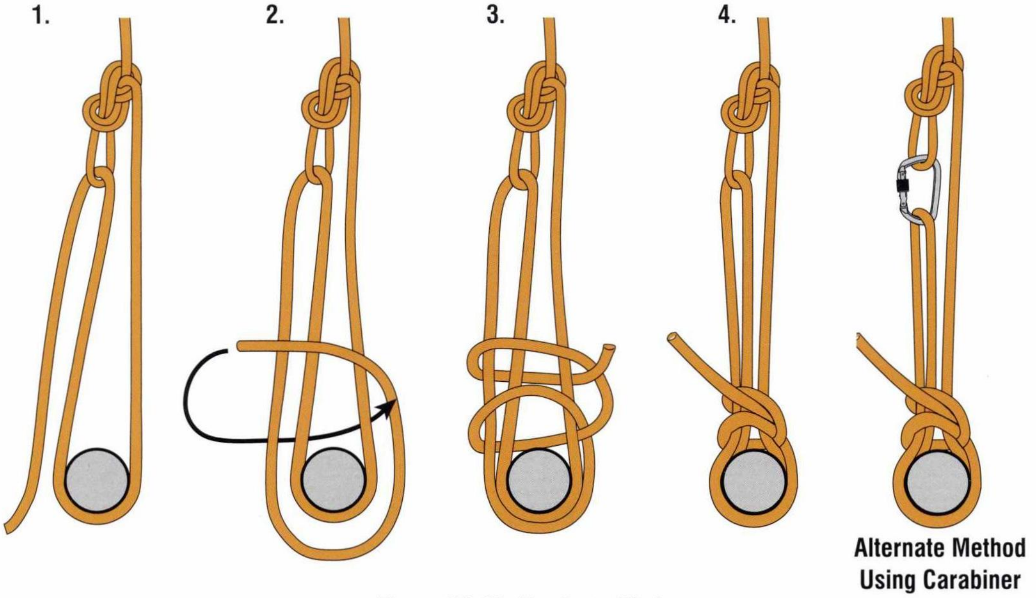


Figure 08-23: Trucker's Hitch

Mariner's Knot

The mariner's knot allows the load to be released from a mechanical advantage ratchet or tandem Prusik Belay for transfer to another device. A rescue runner with at least eight wraps works best, but the knot can be tied with a loop of webbing or cord.

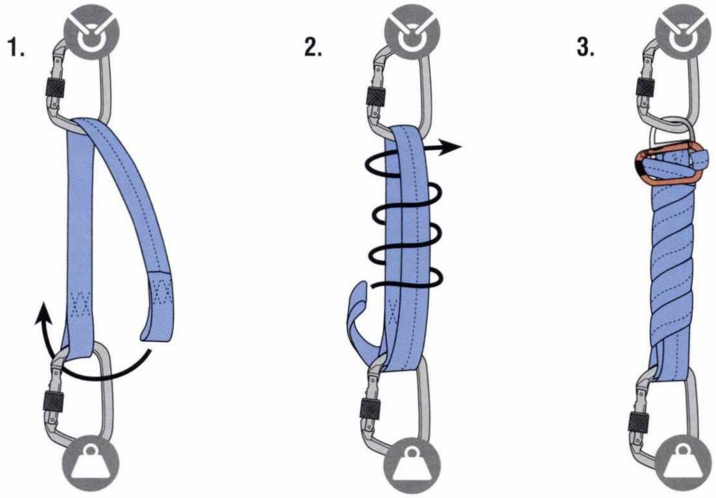


Figure 08-24: Mariner's Knot

Radium Release Hitch

A hitch that allows a ratchet or tandem Prusik to be released without removing the load from the system. While there are many ways to tie a release knot, testing has indicated that the radium release hitch can be untied after significant impact load on the belay line. If there is a system failure causing an impact load, a release hitch tied from cord tends to absorb energy better than the web-based versions.

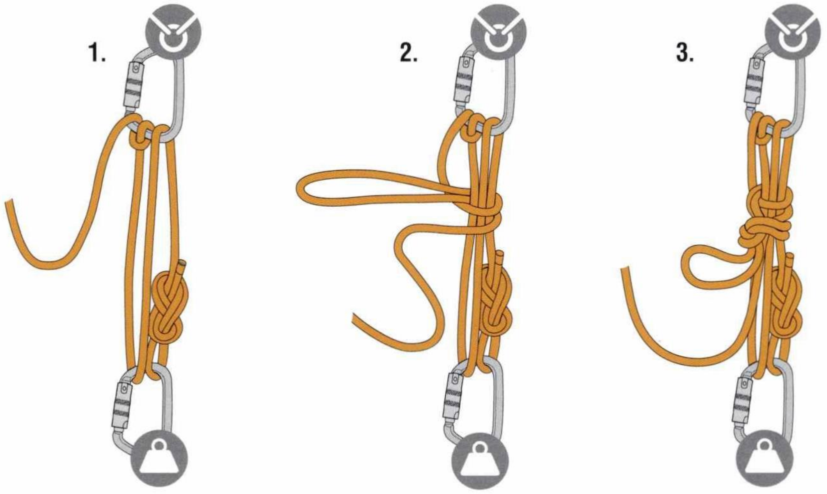
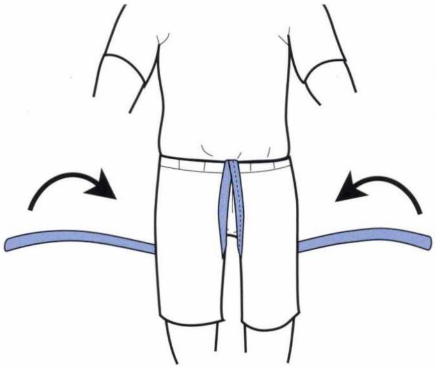


Figure 08-25: Radium Release Hitch

TYING AN IMPROVISED HARNESS

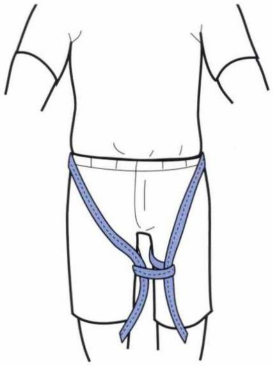
Rope Rescue Technicians are expected to have the proper gear necessary to accomplish the rescue. On the other hand, as skilled Rope Rescue Technicians, one should be able to adapt to unusual situations—such as when the proper gear is not available for either the patient or the rescuer. These improvised harnesses do not provide the same level of protection as a rescue harness. Wear and tear should be watched carefully, see next page.

Hasty Harness



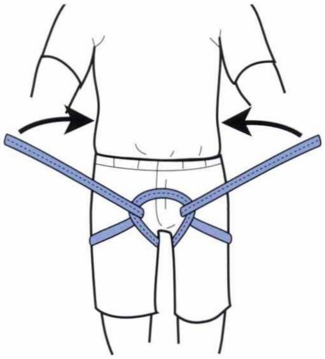
Step 1

Start with a 20 ft (6.1 m) length of one-inch web. Select a point about 6 in (152 mm) away from the center and tuck this point into the front of your pants.



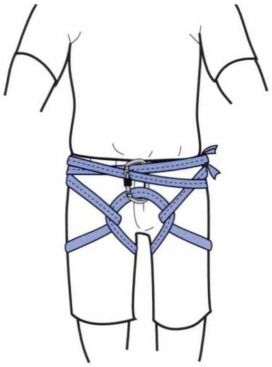
Step 2

Pull the web back between your legs and around the outside of your legs to the front. Insert each end of the web into the loop at your waist.



Step 3

Pull the ends of the web outward and then wrap them around your back. Pulling the web as tight as you can makes the harness more comfortable to hang in. Keep wrapping the extra web around your torso until you run out.

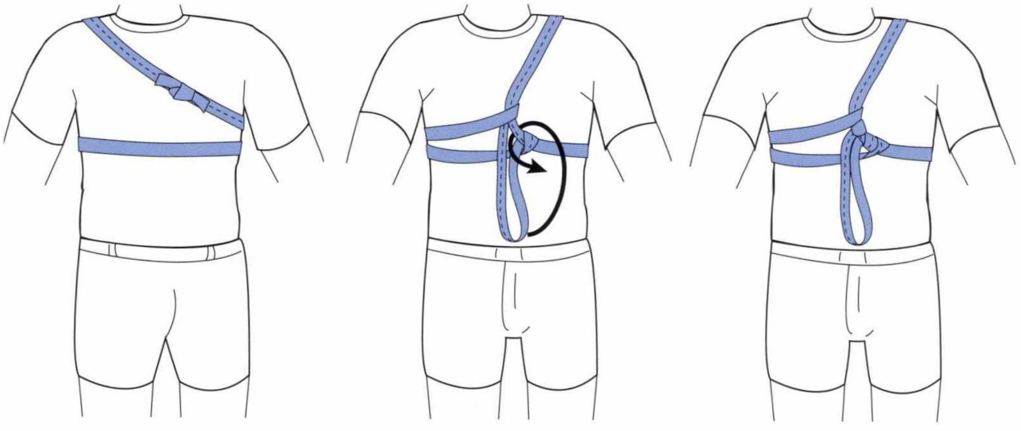


Step 4

Because the center of the web was offset when you started, the ends should come together at one of your hips. Use a square knot to tie the web ends together in order to keep the harness as tight as possible. Back up the square knot with two overhand safety knots on each side of the square knot. Clip your carabiner into the waist loop and the lower web loop.

Figure 08-26: Hasty Harness

Chest Harness

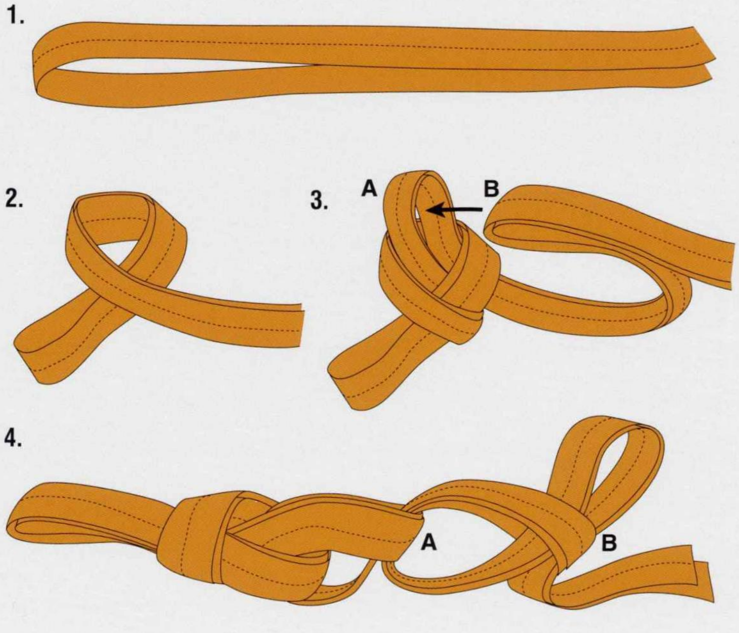


Back **Front** **Front**

Figure 08-27: Improvised Chest Harness Using a Double-Locking Lark's Foot

CMC PRO TIP

A convenient way to carry or store one-inch webbing is to braid or daisy chain a length. This keeps it from tangling and provides a loop at the end for clipping into a carabiner.



Notes

PART
03
Basic Skills

CHAPTER
09
Anchors

TERMINAL LEARNING OBJECTIVE

The student will explain the theory of rescue anchors and describe how to construct simple anchors and their relative strengths.

ENABLING LEARNING OBJECTIVES

1. Describe critical angles in anchors
2. Describe considerations when selecting anchors
3. Describe the common types of anchors
4. Construct the required simple anchor points

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.2.5

Anchors are the foundation that all rope systems are built on and placing a good anchor is a combination of art and technology. It does not matter if the rope will hold 8,992 lbf (40 kN) if the anchor will let go at 90 lbf (0.4 kN). There is no easy rule of thumb that will substitute for experience and judgment. Whether you are working on a cliff or an industrial setting, the best way to learn anchors is from hands-on practice with an instructor or an experienced rescuer.

This chapter focuses on rescue anchors. They are separated from the sport anchors used for rappelling, climbing and caving because of the heavier loads found in rescue work and because rescue workers must rely on anchors that someone else has tied. The knowledge of what makes a good rescue anchor may help you improve your sport anchors.

ANCHOR TERMINOLOGY

Anchor – The generic term for the combination of anchor points, rope, web and other gear to which the rappel rope or rescue systems are attached. An anchor can be simple, backed up, pretensioned, back tied or an anchor system.

Anchor Point – The object that the web or rope is tied to or around. It could be a tree, bush, piton, fire truck, boulder or structure. The ultimate anchor point is a bombproof BFR.

Anchor System – The connection of anchor points together to create an anchor that distributes the load. If a single anchor point in an anchor system should fail, the anchor system will remain intact.

Backed-Up – An anchor that has a second, independent anchor to which the rope is also attached. Since either anchor could support the load by itself, they then back up each other.

BFR – A slang term for a very large rock, but also includes a big tree, fire truck, water tank, stairway or other immovable object. Size is not always the key factor, ***immovability*** is. We have heard of two instances in which a large ***immovable*** rock used for an anchor moved. In one case it was during a low angle litter lowering and the other was during a rappel.

Bombproof – An anchor or anchor point so strong that there is no question in anyone's mind that it will support far more than the expected and unexpected loads of the rescue system. A BFR is usually necessary to make a bombproof simple anchor.

Contingency Anchor System – An anchor system that incorporates a lowering or raising system into the anchor. It allows the rappel line to be immediately lowered or raised to retrieve the person on rappel or a worker on rope.

Critical Angle – The interior angle formed when a loop of webbing or rope is wrapped around an anchor point or when two individual anchor points are connected together (see Figure 09-3).

Load – The generic term for everything that hangs on the rope attached to the anchor. This can include the rescuer, patient, litter, litter tenders, whatever gear they have with them, and the weight of the rope itself. This differs in apparent weight from the load the haul team must pull because they must lift the load plus overcome all the friction in the system.

Load-Distributing Anchor System – An anchor system that spreads the load among two or more anchor points in roughly equal amounts. In theory, the system is self-equalizing, but friction hampers its ability to actually achieve equal loads at each anchor point.

Load-Sharing Anchor System – An anchor system of two or more anchor points with the length of the legs adjusted to place an equal load on each anchor point. How much load ends up on each anchor point depends on the length of each leg of the system and the direction of the pull. Testing has determined that an actual equal load on each leg is not achievable.

Multi-Point Anchor – Another term for an anchor system.

Non-Directional – An anchor system or backed-up anchor where the load on each anchor point remains roughly the same as the direction of pull shifts to one side or the other.

Pretensioned Back Tie – An anchor point that has a pretensioned connection to a second, independent anchor point. The front anchor point acts as the focal point of the back-tied anchor system. The load is primarily on the second anchor point.

Pretensioned Front Tie – Used to remove elongation inherent in an extended anchor system.

Simple Anchor – An anchor with a single anchor point. A high-strength tie-off around a strong tree is an example of a simple anchor.

Self-Equalizing Anchor System – The older term for a load-distributing anchor system. It described the system's theoretical ability to automatically maintain an equal load on each anchor point.

ANCHOR CONSIDERATIONS

There are many factors that need to be considered when choosing an anchor. The placement of the anchor is one factor that can make the difference between a system that works and one that does not. If the anchor is not in line with the load or if the anchor is too close to the edge, a change of direction may be necessary.

The anchor should be built to hold the anticipated loads that will be placed on the system. If the main line runs through a change-of-direction pulley, the force on the pulley's anchor will be greater than the system load. The location of the main line anchor is also a factor in the efficiency of the haul team or the distance the M/A system can be spread out to minimize the number of resets required.

The anchor for the belay line must be able to handle the dynamic load caused by a main line failure. Think about what will happen and where the load will go if there is a main line failure. Location of the belay line anchor is also important because:

- Less rope in the belay system minimizes the distance the load will drop
- Minimum offset will prevent the load from swinging sideways in a pendulum
- The belay system and operator should be a safe distance from the main line

What we tie onto can also make a difference. If we wrap around a steam line, will the heat affect the nylon? What if we use a sturdy pipe that is located near an acid or other chemical that degrades nylon? What if there are sharp edges on the anchor that can cut through the straps? Some of these problems can be addressed. Padding the anchor to protect the straps can take care of sharp edges and maybe even the heat. But if any of the nylon equipment that is used in rescue gets near a chemical that may harm it, it must be retired immediately.

How or where we attach to the anchor can affect the strength. Tying to the base of a tall anchor will reduce the leverage on the anchor, making it as strong as it can be. Choosing the beam that is held on with 12 bolts instead of the railing held on with four bolts would be best. If you think the anchor will hold the load but are not sure, back up the first anchor by also tying to a secondary anchor. Two questionable anchors will not necessarily make one bombproof anchor though. The load needs to be distributed evenly between them; more about that in the next chapter.

When webbing is looped around an anchor point and pulled, an interior angle is formed (q). This is called the critical angle. As this angle increases, so do the forces on each side of the webbing (see Figure 09-2). While some in the industry use 120° as the maximum allowable angle, many prefer 90°. We prefer the 90° as a general guideline since it is easier for most people to visualize and the force going each direction is only 70% of the load. Sometimes it is necessary to exceed 90°, which increases the force on each side. At 120° the force is 100% of the load. Exceeding the 90° guideline is the indicator that the anchor should be rigged for the additional force. Webbing coming together from individual anchor points to create a multipoint anchor system also forms an angle and the same 90° guideline should be applied.

Another concern when wrapping an anchor point or bringing slings together from separate anchor points is the possibility of triaxial loading on a carabiner. As the critical angle increases, the working strength of the carabiner will be compromised. For this reason, many rescuers use a triangular screw link for connecting webbing slings and anchor straps. An alternative is two carabiners connected into an anchor plate (see Figure 09-4).

The Effect of Leverage In An Anchor

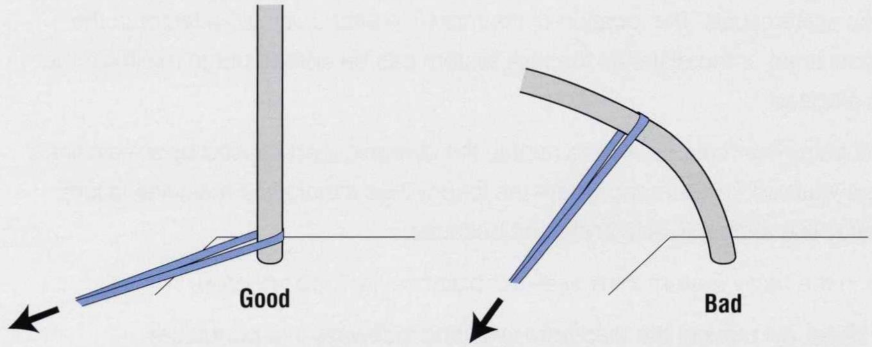


Figure 09-1: Leverage on an Anchor

CMC has always advocated the concept of a redundant anchor for a life support line. It is also possible to "what if" the anchor and have so much redundancy you turn a rescue into a recovery. Ideally, a primary anchor point is perfectly placed, and has a secondary anchor to back it up directly in line to eliminate any shift, should the primary anchor point fail (see Figure 09-4). Realistically, this doesn't always exist. If you find one BFR, you are going to use it. When tying the anchor, look for potential causes of failure. Soft materials, such as webbing, rope or anchor straps, wear with use and exposure to the elements. This could also be caused by the webbing or rope being tied around sharp edges. For all of these reasons, our guideline is to use two separate slings or straps, one to back up the other, or tie a redundant webbing anchor, such as the redundant wrap 2, pull 1. CMC has recently added a second layer of webbing to

Anchor Force and Load Relationships

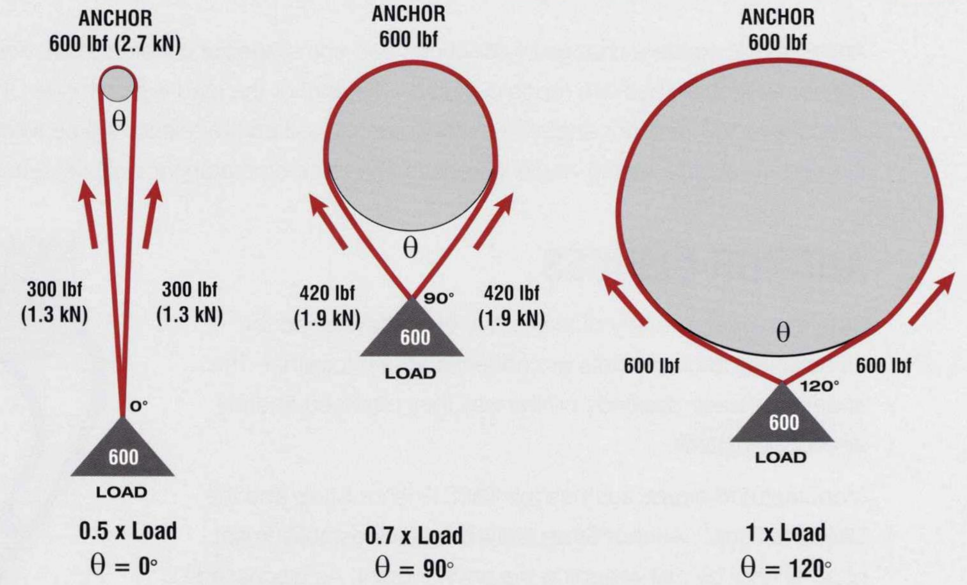

ANCHOR
600 lbf (2.7 kN)
θ
300 lbf
(1.3 kN)
300 lbf
(1.3 kN)
0°
600
LOAD
0.5 x Load
θ = 0°
ANCHOR
600 lbf
θ
420 lbf
(1.9 kN)
90°
420 lbf
(1.9 kN)
600
LOAD
0.7 x Load
θ = 90°
ANCHOR
600 lbf
θ
600 lbf
120°
600 lbf
600
LOAD
1 x Load
θ = 120°

Figure 09-2: Forces on Anchor Web (Rope) Due to Critical Angle (θ)

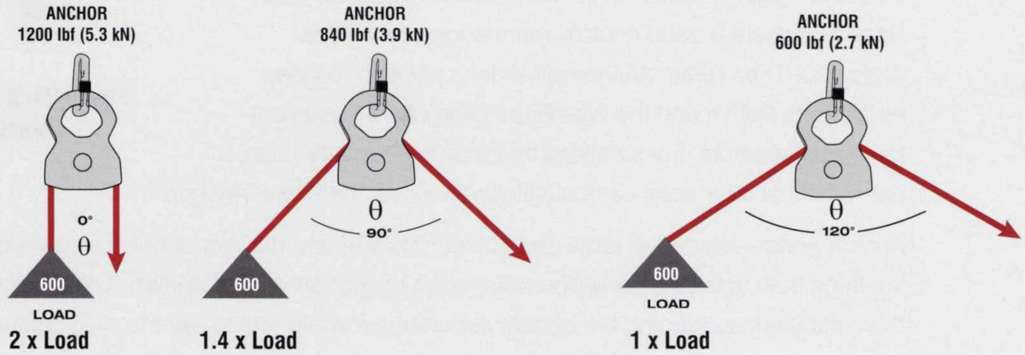
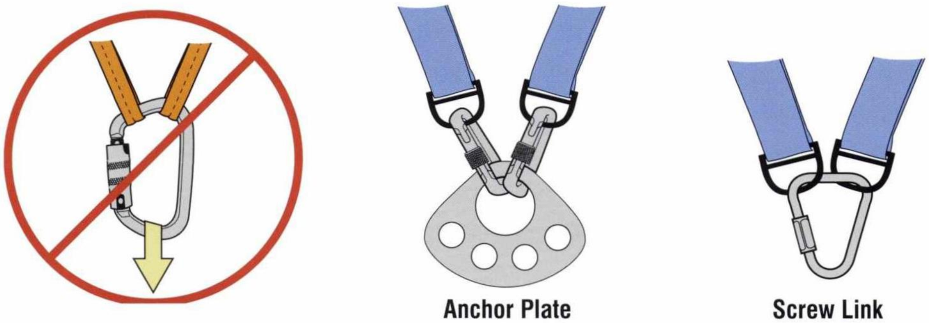

ANCHOR
1200 lbf (5.3 kN)
0°
θ
600
LOAD
2 x Load
ANCHOR
840 lbf (3.9 kN)
θ
90°
600
1.4 x Load
ANCHOR
600 lbf (2.7 kN)
θ
120°
600
LOAD
1 x Load

Figure 09-3: Forces on a Change-of-Direction Anchor as a Function of the Critical Angle (θ)

its anchor straps to add abrasion resistance. If the strength of the anchor point is the concern, the anchor can be backed up to a second anchor point with a pretensioned back tie or a load-sharing anchor system can be created.



Anchor Plate **Screw Link**

Figure 09-4: Triaxial Loading on a Carabiner and Alternatives

Anchors that create a change of direction need some special consideration. First, because the anchor essentially has two ropes pulling on the anchor the load will be higher. If the change of direction is 180° (interior angle is 0°), the force placed on the anchor will be twice the load on the system. As the interior angle increases, the force on the anchor will decrease.

ANCHOR DEVICES

Over the years a variety of tools have been developed for establishing anchor points or connecting them together. The strength of each depends on the way they are used and the anchor point itself.

Manufactured straps such as the CMC Anchor Strap and the CMC FastLink™ Anchor Strap allow the quick establishment of an anchor by just wrapping the anchor point. As discussed above, the interior angle will affect the load on any web or strap wrapped around a point.

Industrial rigging might require more durable anchors. Wire Rope Slings are a good choice where edges cannot be protected. The I-Beam Anchor will slide to position the load as needed. Both it and the Wire Rope Sling can be used as temporary anchors. For locations that may see repeated use, a permanent anchor point can be installed such as the Swivel Anchor.

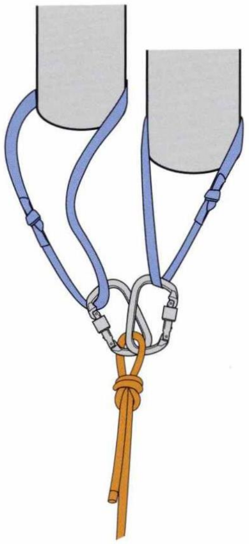
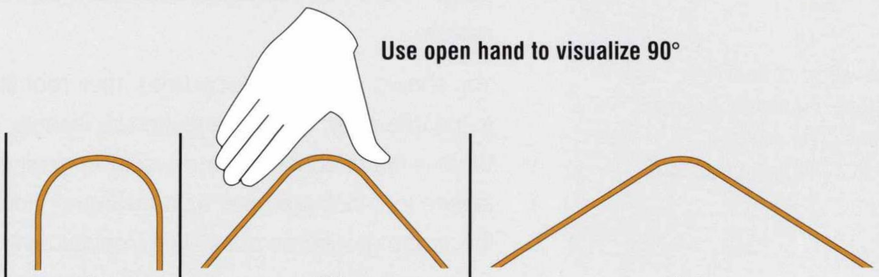


Figure 09-5: Backed-Up Anchor

Anchor plates come in all sizes and colors. The size and number of holes also varies. Generally the large hole acts as a collection point when rigging an anchor system. The small holes keep the carabiners supporting the system separated, making them easier to manipulate.

CMC PRO TIP

Field expedient force calculation for a change-of-direction pulley:



Interior Angle:	0°	90°	120°
Force on Pulley, Anchor and Carabiner:	2 x Load	1.5 x Load	1 x Load

Wire Rope Sling

Bolt-In Anchor

I-Beam Anchor

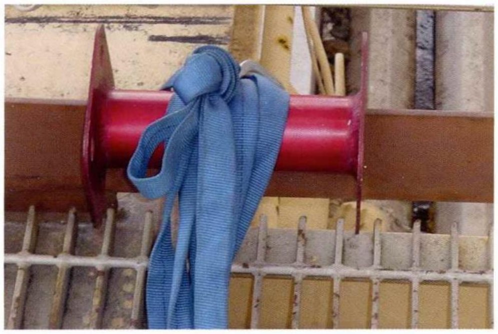
Anchor Strap

Anchor Plate

CMC PRO TIP

If you frequently run into trees with a lot of sap on the bark, consider carrying a roll of plastic food wrap to wrap the tree first.

To estimate the weight of hard rock, such as sandstone or granite, assume that it weighs about the same as concrete—about 150 lb per cubic foot.



SELECTING ANCHOR POINTS

Natural – Trees and boulders are good for setting up quick anchors. Check to make sure that they are solid. Estimate their holding ability based on their size and the condition of the soil. Large bushes can be used, but usually as part of an anchor system.

You should know your local trees, their root structure and depth. Is the tree dead or alive, attacked by insects, burned or hollow? What is the effect of wet or dry soil? In most cases consider at least a four-inch diameter as a minimum. For most trees, tie as low to the ground as possible to reduce leverage and use extra wraps to keep the anchor sling from sliding up.

With a rock anchor point, watch out for sharp edges and pad them if necessary. In sandstone country, recent rain can reduce the holding power of even large boulders and rocks, so be even more conservative after (or during) a storm.

Structural – A building, bridge or tower can be used as an anchor point by wrapping a rope all the way around it, but it is more common to connect to a structural member. Make sure whatever part will be used as an anchor is firmly connected and in good condition.

Many buildings have fittings for window washing or maintenance that would be adequate for rescue systems. Fall protection anchors can be as low in strength as 3,600 lbf (16 kN) but are probably certified by a structural engineer. With bolts, check the direction of pull as they may not be intended for shear (sideways pull).

Try to avoid chimneys, drain lines, electrical conduits and HVAC ducts. Be wary of any pipe that protrudes through the roof, particularly in older buildings that have been remodeled where you are not able to verify what the pipe is connected to underneath. Railings are not a good anchor point since they are designed for a 200 lbf (0.89 kN) downward or outward force but could be used for a focal point with a pretensioned back tie.

Adequate padding and lockout/tagout procedures should allow you to avoid or rig around most hazards. Check the structural parts for:

- Sharp bends that weaken rope
- Sharp edges that could cut webbing or rope

- Chemicals that may damage webbing or rope
- Spray from a broken pipe that could be harmful to rescuers
- Hot pipes that could melt the webbing or rope
- Electrical exposure that could cause a short or energize the rope

Vehicles – Vehicles are often used in roadside, low angle evacuations, particularly when a winch and cable are used as the haul line. Check to make sure the vehicle structure that the web is wrapped around is securely attached to the vehicle. Pad any sharp edges. A litter load with six tenders may be too heavy for a Jeep or pickup-truck size rescue truck. Tie as low as possible to keep the vehicle from tipping. If necessary, anchor the first vehicle to a second one. For vehicle attachment points consider:

- Tow hooks in good condition. Open hooks need to be secured so that the rope or web does not come off
- Frame rails, but watch for brake lines, gas lines and sharp edges
- Wheels, again watch for sharp edges but also hot brake parts
- The center or B-post on vehicles but watch for leverage tipping the vehicle

A common practice is to place one vehicle at the top of the evacuation route and a second down the road. The first vehicle is used as the change of direction and the mechanical advantage system is anchored to the second vehicle. The farther apart the vehicles are parked the longer the pulling distance and the fewer resets of the system. The maximum distance will be determined by the length of the rope. The belay line is usually placed on the front vehicle to minimize the amount of rope in the system.

For added security, be sure to chock the wheels or turn the vehicle sideways. If the vehicle does not need to be running for winch power or lighting, remove the keys and store them in a safe place. Some teams place a placard on the dash or over the steering wheel. Raising the hood is another way to identify that the vehicle is out of service and should not be moved.

Pickets – Picket anchors can be used in situations where there are no other suitable anchors and the soil is conducive to inserting and holding them. Loose sandy soil and solid rock are poor choices for picket anchors.

Pickets should be constructed of sturdy material that will support much more than the intended force placed on them. Rolled steel rod, 1 in (25 mm) in diameter and 4 ft (120 cm) long, squared at one end and pointed at the other, makes a serviceable picket. If other materials are used, downgrade the strength of the picket system accordingly.

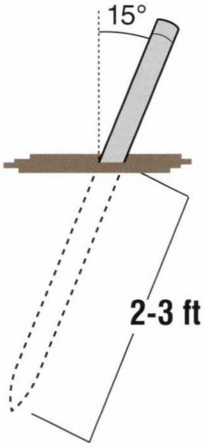


Figure 09-6: Picket at a 15° Angle

Pickets should be driven two-thirds of their length into the ground. The picket should lean away from the direction of the load at a 15° angle from vertical. Separate pickets from each other by 4 ft (120 cm) or the length of a picket.

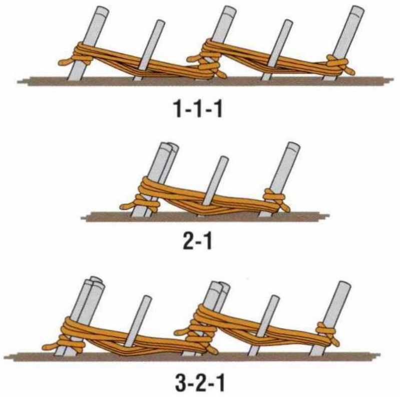
A single picket in hard, compacted soil may be adequate for a single-person load. For systems or two-person loads, connect the pickets together with a Spanish Windlass, constructed with one-inch webbing or rope. Tie the webbing at the bottom of the front picket with a clove hitch, about 2 to 6 in (5 to 15 cm) above the ground. Wrap the webbing around the base of the rear picket in line and back around the front picket. Finish with a Clove Hitch at the base of the rear picket. With life safety rope, use a minimum of two wraps. With one-inch tubular web, use a minimum of four wraps.

To rig the windlass, place a tensioning device between the loops. A rod 18 to 20 in (40 to 50 cm) works well. Turn the tensioning device so that it begins to twist the loops. Continue until the front picket just starts to move. Anchor the device by driving it into the ground or sliding it through the web so the ground prevents it from turning.

In the CMC School classes, we have evaluated a variety of picket patterns and found that in-line pickets generally provide the highest strength. Grouping two or more front pickets can add additional strength. Pickets set up in a V-shape provide better security if the load might shift during the operation.

Tests conducted in our Rope Rescue Technician III class provided the following results for an anchor using three pickets arranged in line.

Class	Soil	Picket	Result
Chico, CA	Soft, moist soil with 1 to 2 in rocks	1 inround steel 48 in long	2,200 lbf (9.79kN) 1 in frward movement
Cincinnati, OH	Soft, moist clay with grass	1 in round steel 30 in long	2,500 lbf (11.12 kN) 1 in forward movement


1-1-1

2-1

3-2-1

Picket System	Strength
Single Picket	700 lb
1-1	1,400 lb
1-1-1	1,800 lb
2-1	2,000 lb
3-2-1	4,000 lb

Use the following factors below to adjust for wet soil

Soil Type	Factor
Clay and gravel mixture	0.9
River clay and sand	0.5

Figure 09-7: Picket Systems

The California State Fire Training's Rescue Systems program field tests have achieved more than 5,000 lbf (22.2 kN) with a three in-line picket configuration in hard, compact soil. For reference, the U.S. Army Rigging Field Manual provides the following for loading picket anchor systems in average loamy soil:

> Multiply the estimated strength of the picket system by the soil factor to obtain the new estimated strength. Because of the wide variation in soil types and conditions, these numbers should be used cautiously and with a wide margin for error.
>
> Use the following factors to adjust for wet soil: clay and gravel mixtures 0.9; river clay and sand 0.5

Hurley Picket Anchor System – The Hurley Picket Anchor System relies on a rigid interface between the anchor plate and the pickets. This allows for a more efficient installation and for each picket to be loaded equally, greatly increasing the pull-out capacity.

The Hurley Picket Anchor System sets up much quicker as the picket spacing is pre-set with the plate and each is driven straight down. The need for a Spanish Windlass to tension the pickets is eliminated, again, saving time. For additional holding capacity, two systems may be connected end to end.

Recreational Climbing Protection – The pitons, chocks, cams, and bolts used by sport climbers are designed to be easily placed one-handed, and are light in weight since a lead climber may place protection every 5 to 10 ft (1.5 to 3 m). With careful engineering, a load distributing system could be designed that will support the higher loads encountered in rescue systems, but be aware of the limitations.

Pitons and chocks both require skill and experience in placement and analysis. The cord used to sling chocks may not be strong enough for rescue loads. Movement in a hauling or lowering system can loosen a piton or a chock. Bolts need to be checked carefully and failure under the lighter climbing loads is not uncommon. A natural anchor point is preferred for a rescue.

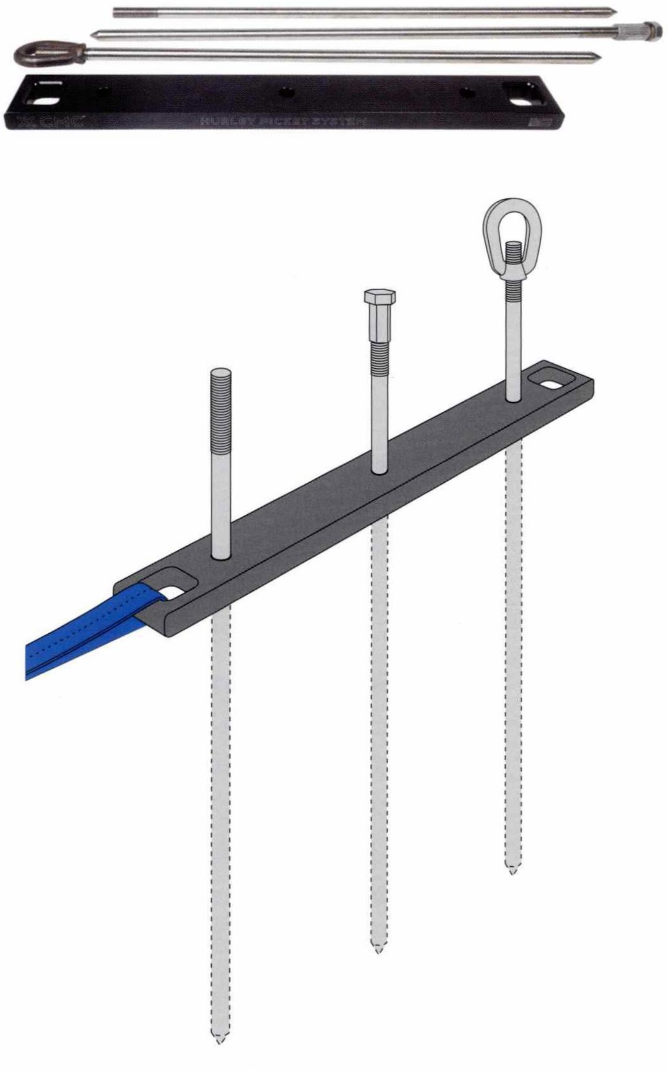


Figure 09-8: Hurley Picket Anchor System

Snow Pickets and Flukes – Snow systems and snow anchors are not within the scope of this manual. We suggest Mountaineering: Freedom of the Hills as an excellent textbook on the subject. Another source is the series of presentations at the International Technical Rescue Symposium by Art Fortini of Sierra Madre, CA. If you need to work in snow, contact a mountain rescue team or ski patrol unit near you which has snow rescue experience to provide training for you.

SIMPLE ANCHORS

A simple anchor consists of webbing or rope tied around the anchor point to which you connect the system. Like everything else in rescue, there are a variety of ways to accomplish this, each with pros and cons. What we learned from testing different simple anchors was that the practical strength often differed greatly from the theoretical strength. We used one-inch tubular and one-inch flat web for the tests and found that the webbing almost always broke where two layers of webbing were pinched inside the carabiner.

For the tests, we used a 90° critical angle both for consistency and because that is our guideline for maximum interior angle. If the angle increases, the anchor strength would decrease. If the angle decreases, the anchor will be stronger. The results are based on one test session. Actual field performance will vary.

Girth Hitch or Choker – Start with a loop of web, then insert one loop through, tying a girth hitch around the post. The girth hitch grips the post, which keeps the webbing from slipping upward, creating greater leverage on the post.

Single Loop – Just wrap webbing around a tree, rock or structural member and tie a water knot. The carabiner will slide to the center in the direction of the pull.

Wrap 2, Pull 1 – Sometimes you do not have a long enough piece of web for a wrap 3, pull 2, so the compromise is just two loops around the post. Positioning the water knot in front of the post may prevent it from taking any load at all.

Redundant Double Loop – Double the webbing or use two pieces of webbing and wrap a loop around the post. Tie the ends together using one water knot. This is quicker to tie than two separate loops of web and much easier to get the two loops to be the same size, so the load will be evenly spread between them.

Wrap 3, Pull 2 – Wrap the webbing around the anchor point three times and tie a water knot. Pull two of the loops out to connect to the carabiner, so that the third loop tightens around the post. Position the water knot so it is on the load side of the post. In most cases, the friction of the post will keep the load from transferring to the knot. Not only is the knot easier to untie, but since it is not loaded, no strength loss occurs.

Basket – Also called a U configuration, first tie the loop and then wrap it around the post and connect it with a triangular screw link. Even though we now have four legs, failure of one will cause the anchor to fail. Also called a "3-bight" anchor.

Double Loop – Two wraps of webbing around the anchor point tied off with a water knot. The carabiner will center in the direction of the pull. To maintain full strength, both loops must be the same size.

Redundant Wrap 2, Pull 1 – This has become a favorite anchor in class. It was the strongest of the one-inch tubular web anchors and second strongest of the one-inch flat web anchors. Because it is tied as a redundant anchor (two pieces or a doubled length of web), when using a BFR anchor point it eliminates the time needed to tie a second anchor.

Other simple anchors include:

Basket with Anchor Strap – Similar to the basket with webbing, this anchor has an anchor strap wrapped around the post and is connected with a triangular screw link.

High-Strength Tie-Off – While the high-strength tie-off or the tensionless hitch may be used to create a very strong anchor, they do have some special considerations. The condition of the anchor point can reduce the rope strength by bending the rope too sharply or exposing it to a sharp edge. Since there is no knot involved, the theoretical strength is equal to the MBS of the rope used to tie the anchor.

TESTING YOUR ANCHOR

A pair of anchor straps around a BFR is obviously an adequate anchor, but if for any reason you have a question about the strength of an anchor, do not hesitate to test it. Give it a pull to see how it will load and to set the knots. If it is a system anchor, have several rescuers pull on it together. Be sure you have a safe space behind you just in case the anchor does fail.

If the anchor point is not strong enough, several anchor points will need to be combined to make an anchor system.

One-Inch Webbing Anchors: Minimum Breaking Strength of Common Configurations

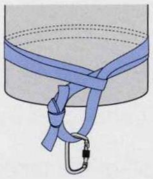
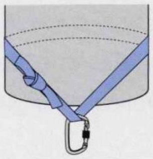
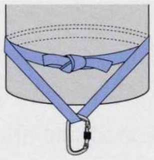
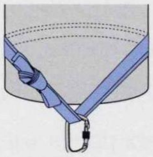
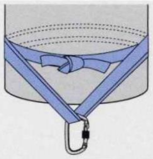
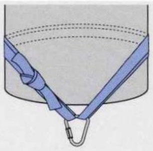
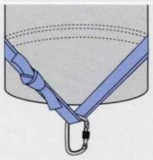
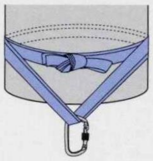
		Tubular Web lbf (kN)	Flat Web lbf (kN)
Web Strength		4,340 (19.31)	6,000 (26.00)
Chocker or Girth Hitch		4,799 (21.35)	8,776 (39.04)
Single Loop (90° Internal Angle)		4,832 (21.50)	6,130 (27.27)
Wrap 2, Pull 1 (90° Internal Angle)		5,510 (24.51)	8,098 (36.02)
Redundant Double Loop (90° Internal Angle)		7,777 (34.59)	10,786 (47.98)
Wrap 3, Pull 1 (90° Internal Angle)		7,899 (35.14)	10,507 (46.74)
Basket (90° Internal Angle)		8,464 (37.65)	12,989 (57.78)
Double Loop (90° Internal Angle)		8,716 (38.77)	10,538 (46.88)
Redundant, Wrap 2, Pull 1 (90° Internal Angle)		9,700 (43.15)	11,458 (50.97)

Figure 09-9: MBS of Common Configurations

PART 03
Basic Skills

CHAPTER 10
Anchor Systems

TERMINAL LEARNING OBJECTIVE

The student will demonstrate proper anchor selection and anchor system construction.

ENABLING LEARNING OBJECTIVES

1. Describe considerations when constructing anchor systems
2. Describe the advantages and disadvantages of multipoint anchor systems
3. Construct a three point load distributing anchor
4. Build a contingency anchor system
5. Construct a pre-tensioned back-tie anchor

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.2.6

When a single anchor point with sufficient strength to support the system is not available, several anchor points will have to be connected into an anchor system. Each anchor point will take some of the load and how much each receives depends on how the system is set up. The length of each leg and the final direction of pull will influence how much of the load each anchor point will see. The anchor system should also be set up so that the failure of any one anchor point does not cause a catastrophic failure of the entire system.

Use an anchor system only when necessary. An anchor system compared to a simple anchor takes longer to set up and can use up a lot of gear.

When an anchor point fails on a load-distributing system, slack is created in the system, and that slack must be removed before the entire system becomes static again. The falling litter and its occupant remove the slack, and the shock load could result in an injury or cause other anchor points to fail. This could snowball when the shock load causes another anchor point to fail, possibly ending in a complete anchor failure. With a main line failure, the belay line will probably catch the load before the slack comes out of the anchor system. If the anchor point failure is on the belay line that is trying to save a main line failure, then this could become catastrophic.

If a load-distributing anchor system is used, keeping the system small will reduce the slack generated by a lost anchor point and thus reduce the shock load that will happen. The one-foot rule, keeping each leg less than 12 in (30 cm), is a good guideline. If the anchor points are not conveniently located, an extension from an anchor point to the anchor system can be used to allow the system to remain compact. Pull the system through the expected sideways range of motion to make sure that it is not too small to function.

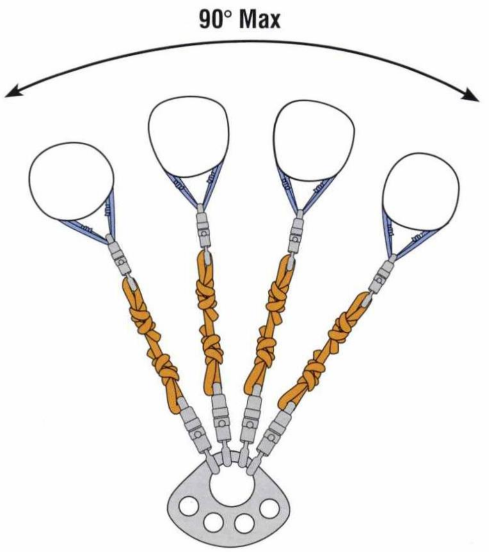


Figure 10-1: Load-Sharing Anchor System

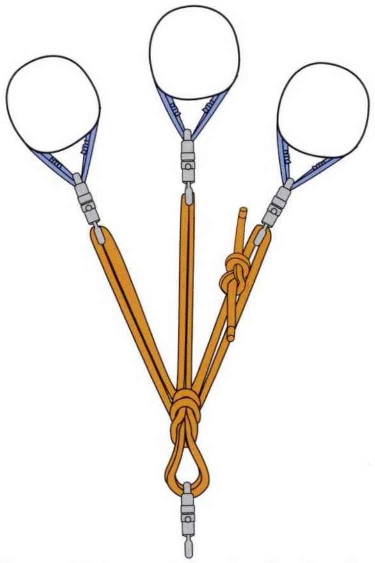


Figure 10-2: Load-Sharing Anchor System

LOAD-SHARING ANCHOR SYSTEM

The distribution of the load in a load-sharing anchor system depends on how the rescuer sets up the system. If each leg has the same tension, then it follows that the load should be evenly distributed. If one leg is longer, its anchor point will carry less than an equal share of the load. Our tests demonstrated that despite being carefully set up, the resulting load on each anchor point was far from equal and there was little consistency on which point was taking the greater share of the load. Also, if the direction of pull on a load-sharing anchor system shifts, one side of the system will begin to take a greater share of the load.

LOAD-DISTRIBUTING ANCHOR SYSTEM

Of the many different ways to tie a load-distributing anchor system, we have found the following system to be flexible, efficient and quick to set up. It can be tied in the end of the rope or with a separate rope. With a little creativity in stacking systems, almost any combination of loads on the anchor points can be designed. While stacking is seldom necessary, it is useful if the strength of the individual anchor points differ significantly

The ability of a load-distributing system to self-equalize is significantly hampered by friction. In most cases, adjusting the system by hand before it is loaded will come the closest to equalizing the load between the anchor points. For an idea of what is going on and what effect an anchor point failure has on the system, see Appendix G for the anchor system test project.

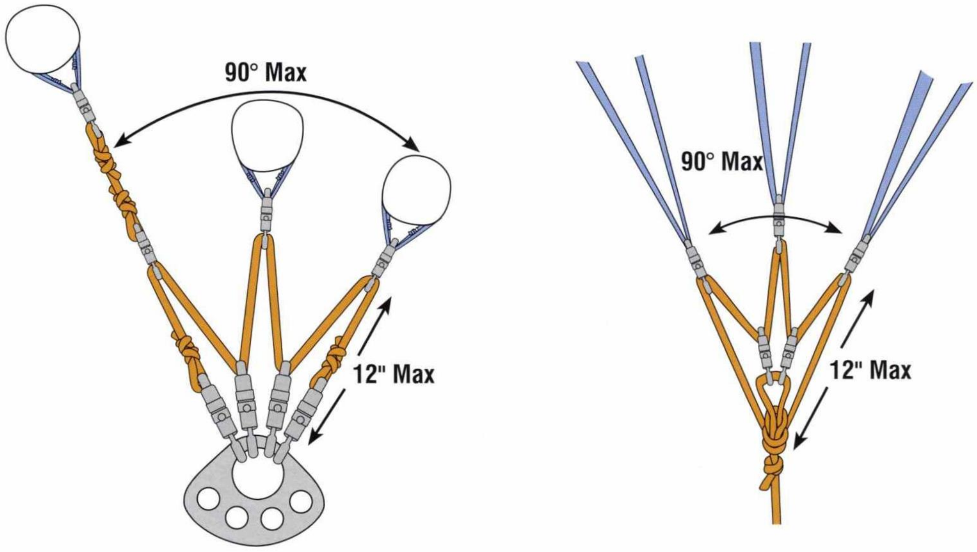


Figure 10-3: Load-Distributing Anchor System

TWO-POINT LOAD-DISTRIBUTING SYSTEM

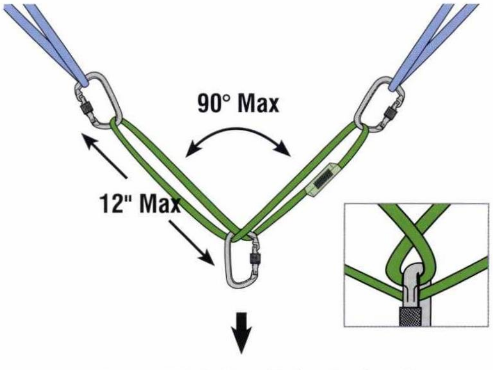


Figure 10-4: Two-Point Anchor System

A quick, two-point system can be made using a small loop of webbing or a Prusik loop. Clip the loop into each anchor point and pull both sections toward you. Twist one strand to make an X with a small loop. Clip both strands with the carabiner going through the small loop (see Figure 10-4). The twist prevents the carabiner from sliding off if one anchor point should fail. When tied with cord, this system usually self-equalizes the load and will be non-directional but limited to only two points. It is popular in snow systems because of the preference for at least two anchor points for each anchor.

PRETENSIONED ANCHORS

A *pretensioned back tie* (see Figure 10-5) can be used when the anchor point in the best position is marginal and will need assistance to support the load. A hand rail at an industrial site or a small tree in a wilderness site are just two examples that could be too weak to support the system. By connecting the marginal anchor point to a bombproof anchor point behind it with a pretensioned back tie, the marginal anchor becomes the focal point where the rescue system is connected while the load is transferred through the pretensioned system to the bombproof anchor point.

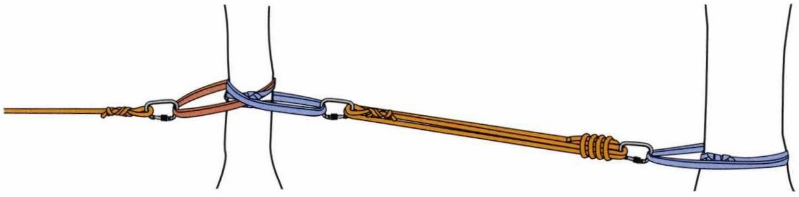


Figure 10-5: Pretensioned Back Tie

The pretensioned back tie can be made with rope or webbing. The more substantial the components, the better the load is transferred to the back anchor. Start by tying a webbing anchor on the front anchor point. Tie a second webbing anchor on the rear anchor point. The two anchor points need to be in line with the force vector of the loaded system.

Connect the end of a rope to the front anchor with a large carabiner. Run the rope through a large carabiner in the rear anchor. Bring the rope back up and through the carabiner on the front anchor and back through the carabiner on the rear anchor. This is a 3:1 M/A system with a change of direction. Finish with two Half-Hitches.

Tie another webbing anchor on the front anchor point, interlocking it through the loop of the web holding the pretension system. Use this loop to connect the rescue system. By interlocking the two pieces of webbing, the system will stay attached to the pretension system if the front anchor should fail. Tension the rope until the front anchor moves back slightly. Grasp three of the ropes tightly and tie off the end of the rope against the rear carabiner.

Build the pretensioned back tie first. Just before loading the rescue system, grasp the middle of the pretension system and pull or push (vector) to remove any remaining rope stretch and then tension the back tie again. The direction of pull must be in line with the pretension system to properly transfer the load. If necessary, use a second pretension system. The direction of pull should bisect the angle created by the two systems.

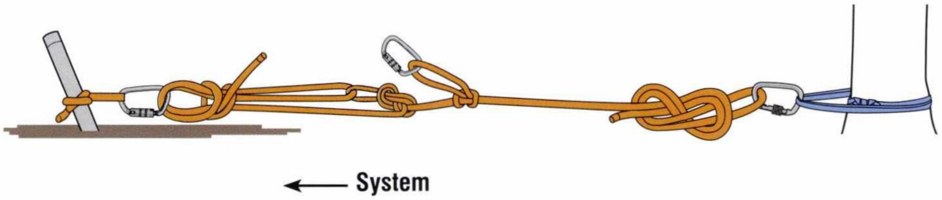


Figure 10-6: Pretensioned Front Tie

A variation of this is the pretensioned front tie, which places the focal point or connection point behind the front anchor point (see Figure 10-6). The tension is used to remove the elongation from an extended anchor.

CONTINGENCY ANCHOR SYSTEMS

A contingency anchor system allows the quick extraction of a person on a rappel line. While a very good plan for conducting a safe training for new rappellers, the contingency anchor is also used by tactical teams to provide an immediate rescue response to an officer on rappel. The anchor system (see Figure 10-7) is essentially a tied-off lowering system rigged for rescue of the person on rope to the ground.

When setting up a contingency anchor system, you will need to plan on having twice as much rope, essentially enough to reach the bottom twice. Start by anchoring the end of the rope and then lower just enough to reach the ground. Rig the rope through the descender and lock it off, including a secure tie-off. If two ropes tied together are used, make sure the connecting knot is on the down side of the descender. Using the CLUTCH or MPD provides the choice of either lowering or raising the load.

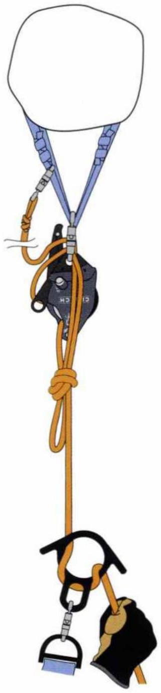


Figure 10-7: Contingency Anchor

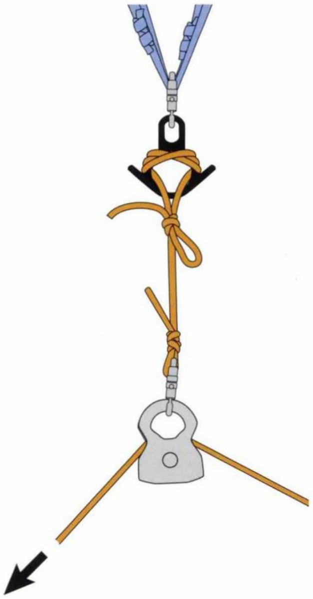


Figure 10-8: Change of Direction

CHANGE-OF-DIRECTION ANCHOR SYSTEM

The angle of the rope at a change-of-direction anchor may result in an increased load on the anchor. If you are setting up for a car-over-the-side and the main line comes up the slope and turns 90°, so the mechanical advantage system parallels the road, the force on the anchor is 1.4 times the load.

When setting up a change of direction, you need to determine where you want the pulley to be when the system is under load. Putting tension on the main line will help you visualize the final position of the pulley. The force vector on the anchor will bisect the angle made by the main line, and this will help you determine if the anchor has the best orientation to handle the load.

A variation on the contingency anchor system will help you rig a change-of-direction pulley in the right place when you are not sure how far the pulley needs to be from the anchor. This often occurs when a long low angle evacuation needs to make a slight bend. Set up the anchor so that the pulley is closer to the anchor than to the centerline of the evacuation route. Lock off the descender. When the system is loaded, let out the rope holding the pulley until the system is where you want it to be. When the litter reaches the pulley, unlock the descender and pull the rope to create enough slack for the litter team to remove the pulley.

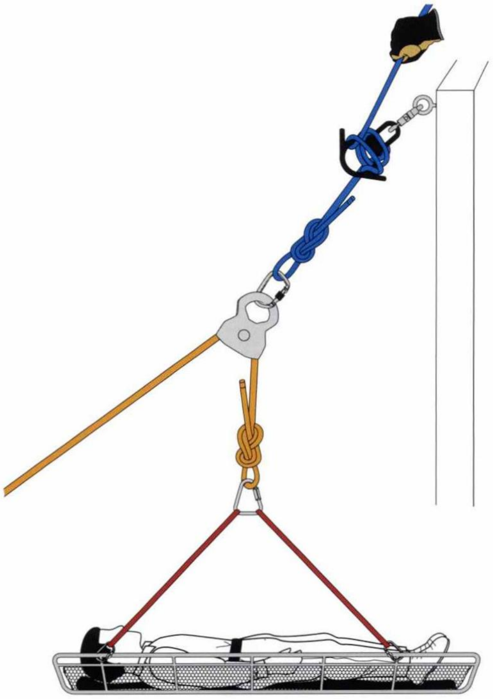


Figure 10-9: Counterforce Anchor System

COUNTERFORCE ANCHOR SYSTEM

When working on open structures, such as ladder cages or towers, a counterforce anchor system can move the litter away from the surface. Tension on the rope from the haul team, either for a raising or lowering, will pull the litter away from the surface.

Use a descender (see Figure 10-9) to extend the pulley. Rig it with a length shorter than you anticipate needing, then let out rope until the load clears the obstructions, then lock it off. Moving the location of the operators will also change the bisect of the angles and can control the descent path.

PART
03
Basic Skills

CHAPTER
11
Edge Protection

TERMINAL LEARNING OBJECTIVE

The student will identify different types of edge protection and explain where it should be used in a rope rescue system.

ENABLING LEARNING OBJECTIVES

1. Describe the different locations where edge protection could be required
2. Identify the four goals of using edge protection
3. Identify the different types of edge protection devices

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.2.8

Ropes seldom just break; failure comes from cutting or abrading over an edge.

The history of rope failure in climbing and caving accidents all were situations where the rope suffered abrasion or received an impact load while bent over an edge. Abrasion occurs at any location where a moving rope touches the surface. Usually, the more the rope bends, the higher the level of abrasion. At greatest risk is a fixed line that saws back and forth as it is loaded and unloaded.

Bending a rope over an edge also weakens the rope. The sharper the bend, the more the rope will be affected. The risk of failure results from an impact load over the edge coupled with any sideways slide across the edge that begins to cut fibers.

Edge protection is even more important for a rappel rope or a fixed line than it is for a rescue system. As the person on the rope moves, there is always some movement across the edge. As the length of rope increases, the amount of sawing at the edge also increases, along with the risk of significant abrasion.

GOALS IN PLACING EDGE PROTECTION

Protect the Rope – The primary goal is to protect the main line and the belay line from abrasion and sharp bends. The rope should also be prevented from digging into soft surfaces, such as a dirt roadside.

Protect the Surface – A tarpaulin or edge pad can protect the edge from the rope. This prevents loose material, such as dirt and rocks on a roadside, from being knocked down on the people below. When training on structures, avoiding damage by the rope to the building will help keep the facility owner happy.

Reduce Friction – It requires extra energy to overcome the friction created by a rope dragging over an edge. The higher the friction, the greater the force placed on the rope and a corresponding reduction in the safety margin. The best solution is to mitigate the sources of friction; otherwise you will have to add people to the haul team or increase the mechanical advantage.

Keep the Rope Clean – While not of immediate importance during a rescue, keeping the rope clean is good rope care that will help rope last longer. In muddy or icy conditions the reliable performance of pulleys, ascenders or Prusik hitches may depend on keeping the rope clean.

EDGE PROTECTION EQUIPMENT

Edge protection equipment can be combined for maximum performance or improvised at the scene. Depending on the location and type of edge, there are several options:

- **Protection** – protects the rope and edge
- **Protection and a sliding surface** – protects and reduces friction
- **Protection and a rolling surface** – protects and reduces friction
- **Moving the rope away from the edge** – protects and reduces friction

The more the rope moves, the higher the level of protection is needed. Also, reducing edge friction can result in a significant reduction in the force needed to lift the load.

Edge Protection

An *edge pad* is a sheet of heavy material used to separate the rope from the surface. It smoothes out rough surfaces and keeps the rope out of the dirt. They can be wrapped around a tree or pole to protect from sap or creosote. Edge pads achieve the above although their ability to pad or smooth edges depends on their stiffness. However, they are limited in their ability to reduce friction.

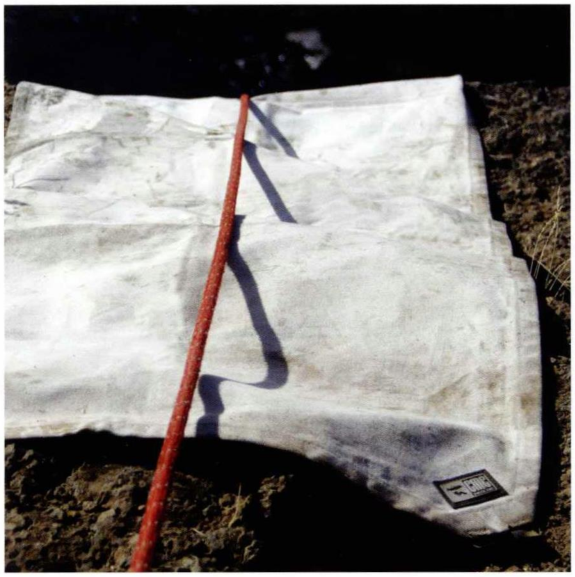
For edge-pad material, CMC recommends canvas. Nylon material and some plastics can be melted by the heat generated from a moving rope. The stiffer the material, the better it will work for smoothing out a rough surface. Smaller pads can be wrapped around anchor points to protect the rope, the web or the anchor point itself. On steep terrain, anchor the pad to keep it from falling. Even when edge rollers are used, an edge pad underneath them will help protect the ropes if they come off the rollers.

The developing terminology refers to an edge pad as a surface covering, while an *edge guard* or *rope guard* refers to something that wraps around the rope. Early models were made from a short length of retired fire hose with a lengthwise cut to fit them over the rope. Commercial edge guards wrap around the rope and close with hook and loop to keep them on the rope. They are available in a variety of lengths.

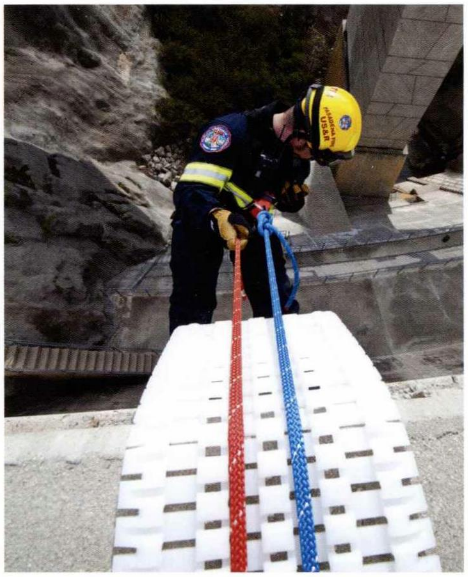
Edge guards can be used to meet all of the above goals, but like the edge pads, they have limited ability to reduce friction. They are excellent for protecting fixed lines and also anchor straps.

The edge guard can be tied off with a piece of cord to keep it in position. The cord can go to a separate anchor or can connect to the rope with a Prusik or clove hitch. Make the cord long enough so that the edge guard can be slid up the rope to make room for a descender when you start a rappel. Before the rope contacts the edge, slide the guard back into position.

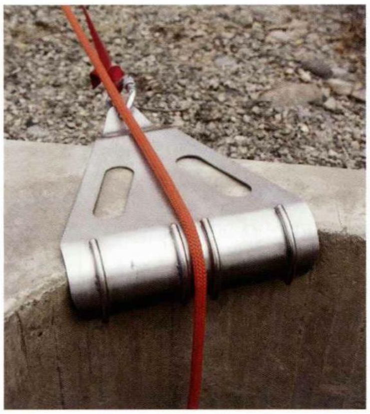
On a long system or rappel, in which the rope is exposed to abrasion in several places, take along edge guards or edge pads. As you pass a possible abrasion point, put the protection in place and secure it with a cord. If someone follows you down the rope, they will have to remove the edge guard and put it on again after passing the point. It will help if you anchor the



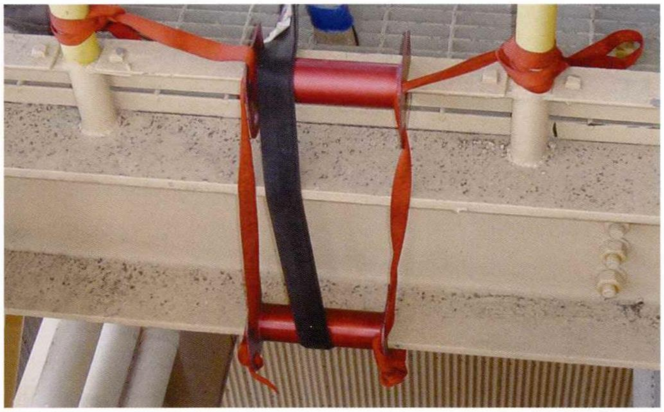
Edge Pad



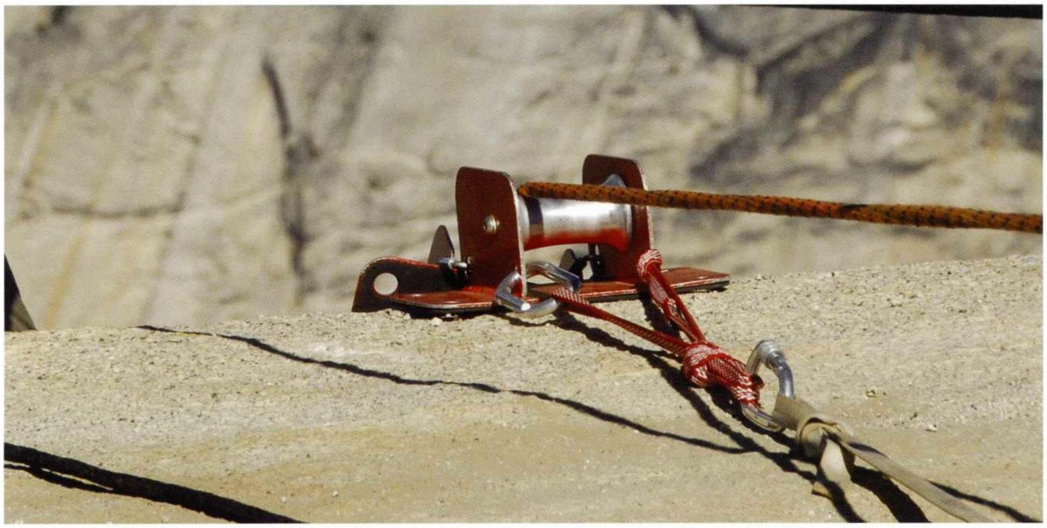
Ultra-Pro Edge Protector



Born Entry-Ease



Industrial Edger



Edge Roller

protection on something other than the rope. With the stretch in a long rope, this helps keep the protection at the edge and makes it easier to pass since the person on rappel just needs to open the edge guard to move it out of the way.

Multiple edge guards can be attached with a long cord. Stack them at the top and as the rescuer is lowered, the protection can be placed where needed. When the rescuer comes back up, the edge guards will be collected by the system.

Protection and a Sliding Surface

Ultra-Pro™ Edge Protectors were developed by Texans Kent Stansell and Lee Foster. The slippery, space-age plastic surface significantly reduces friction while also providing a smooth surface for the rope. They are flexible but retain enough stiffness to create a smooth curvature over the edge, thus minimizing loss of rope strength caused by the rope bending over a sharp edge. Ultra-Pros are available in two-rope and four-rope models.

Corner holes allow secure anchoring or the connection of the units together. While they do not provide as much ground clearance as an edge roller, they are not prone to tipping and are easier to move the litter over once it reaches the edge. The Ultra-Pro 2 fits easily inside a rope bag, so you always have edge protection and friction reduction with you.

For industrial applications, the slot in the Industrial Edger fits over I-beams or toe boards. The Born Entry-Ease provides a protective surface for the entrant as well as a rope when entering a manhole or similar opening.

Protection and a Rolling Surface

Edge rollers come in several shapes and sizes. There are SMC's familiar Edge Roller and Roof Roller and similar designs from other companies. Most of the large knot pass pulleys or high-line carriages have flat bottoms that allow them to be used as edge rollers. The amount of friction can increase significantly if the edge causes the rope to bend sharply. By adding edge rollers to the system, the number of people needed for the haul team will be reduced.

Edge rollers lift the rope several inches above the surface. This provides good clearance but makes the roller unstable if the rope moves off center. This usually happens as the litter nears the top and the angle between the main line and the belay line increases. The rollers all have a wide base for stability, but eventually the rope will flip the rollers onto their side. It may be possible to lift the rope enough to move the rollers. If not, be aware that flipping may happen, which is why we place an edge pad underneath.

Always anchor the edge rollers so they cannot fall, whether they are on a gently sloping roadside or the roof edge of a tall building. We usually use one-inch tubular web because we have a lot of it around, but anything that will support the weight of the rollers will work. Tie off the rollers before putting the rollers anywhere near the edge. Using stakes or tent pegs through the holes of an edge roller to keep it in place has been suggested. We do not think this will keep a roller from flipping, and if it does, it could throw the stakes into the air.

Moving the Rope Away from the Edge

The rope can be run above the edge by connecting a pulley to an anchor point on a portable high-anchor device or convenient tree (see Chapter 30). Some teams have a boom attached to their rescue vehicle. If properly designed and set up, such a device provides edge clearance and can make it easier for the litter team to climb over a roadside berm.

A change-of-direction pulley can be used to pull the rope away from the edge. When an evacuation needs to turn a corner, a change-of-direction pulley can be set up as discussed in Chapter 10. Not only does this keep the litter team out of the brush, but it reduces friction on the rope.

EDGE PROTECTION TEAM

On a big wall rescue, on a rescue that involves a car down a deep canyon or on a long cave rescue, there may be numerous places where the rope will contact the edges. It may be necessary to designate an edge protection team that stations personnel at each location to place and manage the edge protection.

The edge protection team follows the system down on separate rappel lines and sets up edge protection as needed for the rescue ropes and their own rappel lines. When the evacuation is over, the lowest person ascends first. As they passes their edge protection, it is broken down and the next lowest person starts up.

ROPE SELECTION

Low-stretch kernmantle ropes were developed by cavers in the Southeast U.S. partly in response to abrasion problems. Because not every foot of the rope can be protected, selecting a rope designed for high abrasion situations makes sense. There is usually a primary edge that will cause the greatest exposure and most friction. Other points can be protected as time and equipment allow.

If a rope shows badly worn spots during inspection or if ropes are wearing out quickly, more edge protection is required. When additional or better edge protection is not possible, then a rescue rope with the highest possible abrasion resistance should be used.

PART
03
Basic Skills

CHAPTER
12
Patient Packaging

TERMINAL LEARNING OBJECTIVE

The student will learn the different methods for properly securing a patient into a litter for a high and a low angle evacuation.

ENABLING LEARNING OBJECTIVES

1. Demonstrate how to secure a patient in a rescue litter using a commercial tie-in system
2. Demonstrate how to secure a patient in a rescue litter using an improvised webbing method
3. Describe the considerations for packaging for different litter orientations

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.2.20

The litter is a frame that protects the patient from further harm during transport. It also makes the patient easier to handle and to move. The patient must be secured inside the litter, taking into consideration security, comfort and protecting the patient's injuries.

The type of transport will determine how securely the patient must be tied into the litter. A short, low angle evacuation or a carryout using a litter wheel may only require an external tie-in, but even a simple carryout may require tilting the litter to clear an airway. A vertical lift with the litter inline, or a helicopter hoist, would require a much greater level of patient support and security.

The straps that come with most litters are not adequate for high angle, low angle or rough terrain evacuations. They do not provide the necessary restraint in all directions if the litter tips or rolls over.

While some litters come with padding and some do not, neither are adequate for a long term carryout or a technical rescue. A ***litter insert*** provides a comfortable surface for the patient or you can pad the bottom of the litter with a blanket or foam pad. A mesh insert may be cooler on a hot day and allows any fluids, such as water, to drain.

For an extended carryout, a full-body vacuum splint can greatly increase comfort by conforming to the patient's shape. They are a great insulator, which makes them an advantage in cold weather, but may be a problem in a hot environment. Be careful on an older litter with the wire mesh as broken strands could injure the patient.

If the patient's condition is serious enough to warrant a litter evacuation, then the mechanism of injury probably requires placing the patient on a spine board. The spine board can then be tied to the litter at the head and mid-thigh. Finish with an external tie-in.

LOADING THE PATIENT

First, stabilize the litter so that it does not move. On a low angle slope, the rope system can hold the litter in an in-line position. If necessary, turn the litter sideways and place a rock or knee underneath to level it.

Low Angle Slope

Often the patient can assist efforts to put themselves into the litter, so it never hurts to ask. The medic can help support and move any injury, while the patient moves most of their weight.

Carefully lifting a patient requires five or more persons, including one supporting the head. As the angle of the terrain increases, fewer rescuers can work around the patient without getting in each other's way or becoming tangled in the litter straps. Often the best move is to lift the patient just enough to slide the litter underneath from either end, rather than trying to crawl over the litter while holding the patient.

If the patient is in a head-up position on a steep slope, support them until the pelvic harness can take the weight. If there is any delay in transport after packaging, patient comfort will be improved by turning the litter sideways to the fall line and propping it so it is level.

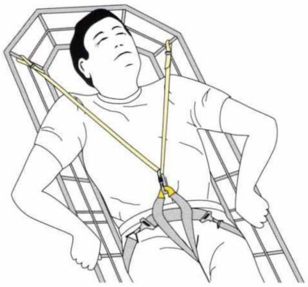
Vertical

If the patient is hanging in a harness, the rescuers may be able to scoop the litter up under them and then either raise the litter until it takes their weight, or lower the litter harness legs which are independent of each other, one leg can be lengthened, or even unclipped, to help slide the litter below the patient. Remember, if there is any chance of the patient falling, keep a belay line attached to the patient at all times. A Pick-Off Strap connected to the top of the litter harness works well for a belay that can be easily adjusted. The strap can be left on as an extra safety belay for the patient; just be sure that it is long enough to allow the harness legs to be lengthened without pulling the subject up out of the litter. With any patient hanging in a harness, suspension trauma must be considered when treating and packaging.

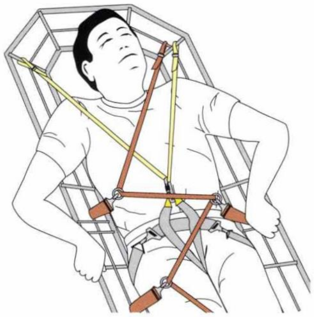
Patient Position

Usually the patient lies on their back in the litter. An unconscious patient can be tied in a lateral recumbent position to help protect the airway.

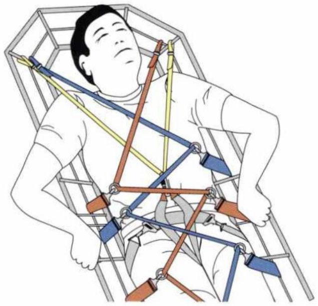
PATIENT TIE-IN SYSTEM



Step 1: Start by moving the external tie-in straps (red and blue) out of the way to the side of the litter. If using the pelvic harness, place the pelvic strap (yellow) at the top of the litter. The pelvic harness can be slid under the patient's legs from the center to the outside.



Step 2: Connect the buckles on the pelvic harness and snug the legs loops, making sure the patient is comfortable. Connect the yellow strap to the pelvic harness with a carabiner and adjust the slack out of the webbing. The intent is to prevent patient movement, not to suspend them in the harness.



Step 3: Clip one color of the external tie-in to the snaps on the other side of the litter and then adjust. Do the same with the second color, then adjust to thoroughly secure the patient in the litter.

Figure 12-1: Patient Tie-In System

While a commercial patient tie-in system is an extra piece of specialized equipment, it allows a very efficient patient packaging. The wider web on the pelvic harness provides greater patient comfort. The patient tie-in system can be left installed in the litter, ready to go. In the following description, we have used the web colors from the CMC Patient Tie-In System for better clarity.

IMPROVISED TIE-INS

If the patient is wearing a harness, attach the harness to the top of the litter. Attach a 12 ft (3.7 m) length of one-inch webbing to the harness D-ring with a girth hitch. Bring both ends up to a vertical tube above the patient's shoulder and connect with a round turn and two half hitches or clove hitch (see Figure 12-2).

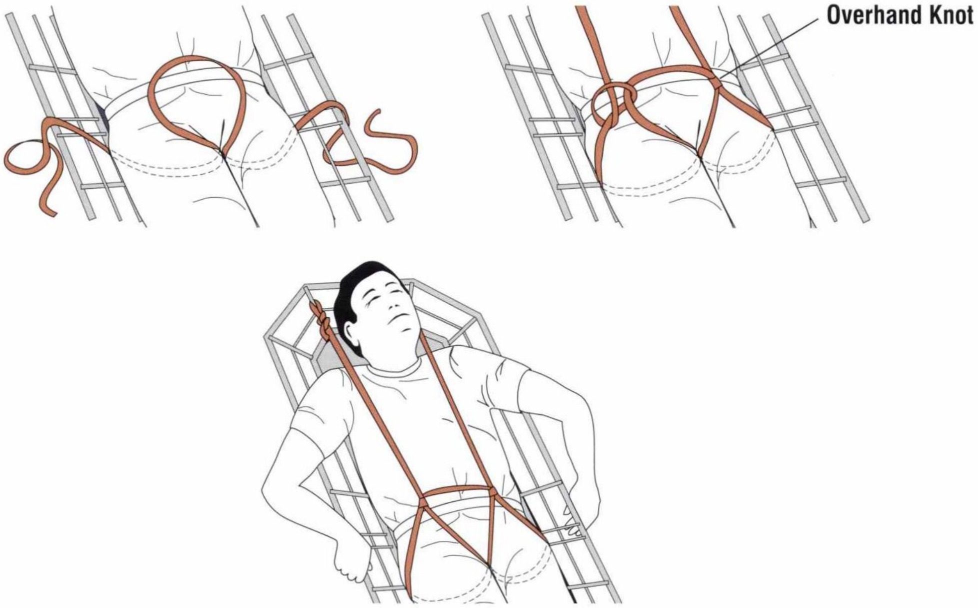


Figure 12-2: Pelvic Harness

Internal Pelvic Tie-In

An improvised pelvic harness can be made with a 20 ft (6 m) length of one-inch webbing. Lay the webbing across the litter before putting the patient in. After the patient is in the litter, pull the center of the web up between the patient's legs until the bight is at the waist. Bring the ends from the outside over the legs and tuck them through the bight. Pull it snug, similar to tying a hasty harness. With each end, tie an overhand knot around the bight and run the web over the patient's shoulders to the head of the litter. Tie the web around a vertical tube using a round turn and two half hitches or clove hitch.

Chest Tie-In

A chest harness prevents the patient from sliding toward the head of the litter if the litter is tilted head down or starts spinning in a helicopter lift. Both options use the 12 ft (3.7 m) length of one-inch web. Option A uses two lengths with an overhand loop in one end of each piece. Option B uses just one length of web. Start by laying the web in the litter (see Figure 12-3). Place the patient in the litter on top of the web. Bring the web over the patient's shoulders and finish as shown. Pull until snug and then use a round turn and two half hitches or a clove hitch to tie the end of the web to a vertical down tube.

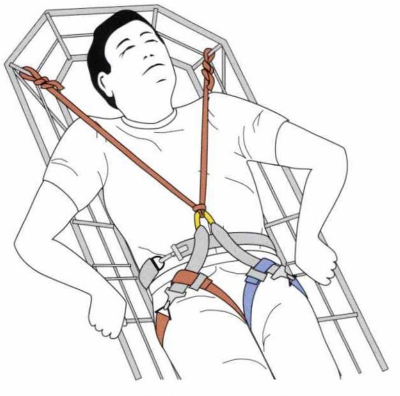
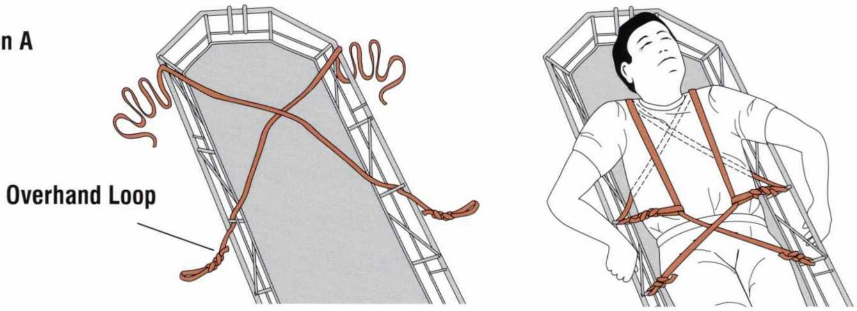


Figure 12-3: Lifesaver Victim Harness

Option A



Option B

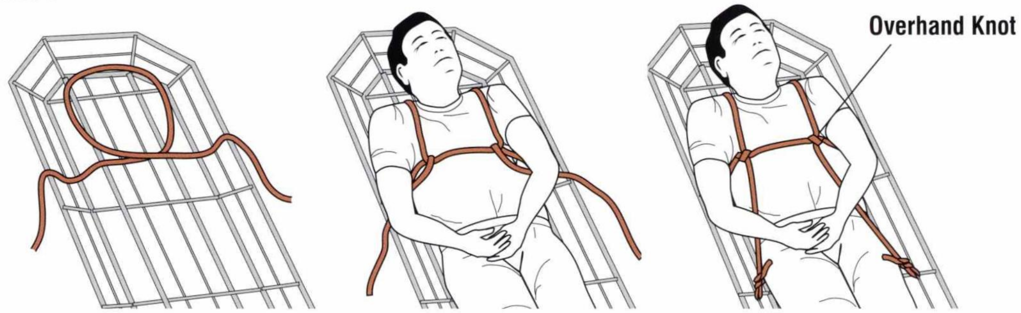


Figure 12-4: Chest Harness Options

External Tie-In

An external lashing is used to hold the torso and legs in the litter. Insert a 20 ft (6 m) length of one-inch web between the upper rails of the litter just below the vertical tubes located next to the midpoint of the patient's legs below the knees. Pull the web through until the center point of the web is between the patient's legs. Bring the ends of the web around the vertical tube, across the patient in a big X and around the next set of vertical tubes toward the patient's head. Continue until the vertical tubes by the patient's shoulders are reached. Skip past those and connect to the vertical tubes by the patient's head. Tie one end of the web to the vertical tube with a round turn and two half hitches or clove hitch. Tighten the webbing by backing down from the tied end and then back up the opposite side. Finish with a round turn and two half hitches or clove hitch.

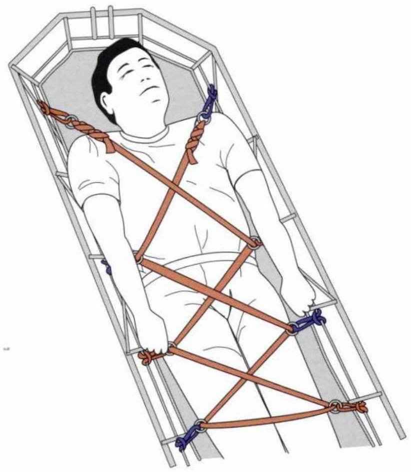


Figure 12-5: External Lashing

Our school litters have eight CMC Litter Loops girth-hitched to the second rail on the litter. The litter loops make the webbing quicker and easier to thread and adjust as compared to reaching around the patient to find and wrap vertical posts. Use a round turn followed by two half hitches to secure the two web ends to the upper litter loops or vertical posts.

When the external tie-in is finished, make sure that the web does not push on any injury. Tie a splinted arm or leg carefully, so that it will not fall out of the litter but also will not have any extra weight or tension placed on it.

Plastic litters and some lightweight wire basket types will flex when lifted. If the patient is tied in while the litter is suspended, the external tie-in will tighten when the litter is placed on the ground and the load comes off the litter harness. If the patient tie-in was tight when the litter was suspended, the straps will be very tight when set down.

Hands

The emotional need for security may cause a conscious patient to grab onto something and this will usually be the litter rail. Any fingers outside the litter are susceptible to injury. The hands can be tied together, but also run a length of web through the hands so that the patient can hold onto it. This gives the hands something to grip, making the patient feel more secure. Having the hands tied while in a litter can be very claustrophobic, so wait until the last moment to tie the hands.

For an unconscious patient, tie their hands together in front of them. A length of web can be tied to one side rail, looped several times around the hands and then tied to the other rail. This will keep the hands in the center. Or leave the patient's hands by their side and under the external tie-in.

Head

The head needs to be protected rather than tied down. Actual immobilization should be done with a spine board providing full spine protection. Wrapping a rolled blanket in a horseshoe shape and placing it around the head will help to stabilize and protect the head from being banged. The head should be protected from any debris that may fall from above with a litter shield or a helmet with a face shield.

PATIENT PROTECTION

A patient tied into the litter is helpless to protect themselves. Exposed to rockfall, brush, flying debris and the weather, the patient depends on the packaging for protection.

From the Environment

Rain falling in an injured patient's face is an unnecessary irritant when they are strapped into a litter. More important, a wet patient can easily develop hypothermia during a long transport because their ability to move and generate warmth through exercise has been lost. If the weather is the least bit cool or will turn cool, cover the patient with a blanket or put them into a sleeping bag. A waterproof cover will help keep the patient dry during inclement weather or when traveling through wet brush or woods.

Helicopter rotor wash is the usual source of very high wind on the patient. The patient, and particularly the patient's eyes, need to be protected from blowing objects. High wind levels from rotor wash increase the chance of the patient developing hypothermia.

Sun glaring in the patient's eyes can be painful and a sunburn during a long carryout is a possibility. The best solution for this is just to remember the patient's situation and be sure not to leave their face in the sun. If shade is not available, position a rescuer to shade the patient. If the patient has a shield over their face, sunglasses may help or something can be placed on the shield to block the sun. Be careful about putting a cloth or other opaque item directly over the patient's face. This could create a claustrophobic situation or even interfere with the patient's breathing.

From Objects

Rockfall is a potential risk and danger in wilderness rescues and roadside evacuations. The urban setting may not have the same risks, but the patient still must be protected from anything that might be dislodged by a moving rope or be dropped from above. A helmet provides some head protection but is not comfortable for a person lying down and leaves the face exposed. Putting a helmet on the patient may also interfere with the immobilization of the spine. Goggles provide eye protection, but a face shield attached to the helmet protects more of the face. Such a face shield should be capable of being tilted out of the way if necessary.

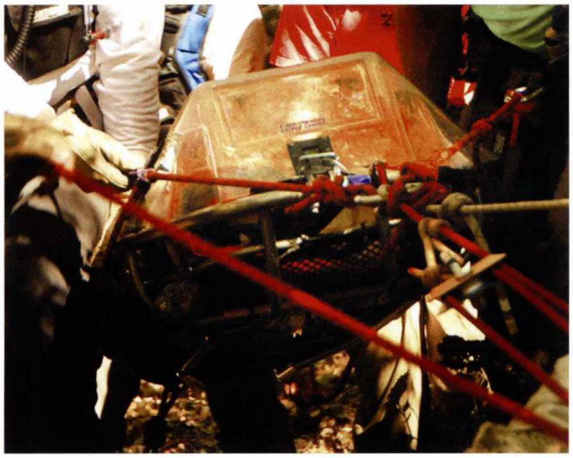
Operations on thick, brush-covered hillsides, such as our Southern California chaparral, risk the patient being stabbed or deeply scratched by a branch. Usually the litter team tries to protect the patient's body with theirs, but the patient's head and face at the front of the litter may still be exposed. A helmet and face shield give some protection but may deflect a branch into the patient's neck or shoulder.

A litter shield provides the best protection for the patient while still providing access to their head. A shield keeps the rain off the head and deflects the wind. Rockfall bounces off and branches slide by. The clear material allows a good view of the patient, and there is sufficient clearance for the medic to reach the patient's face and neck. The patient's body can be further protected from rocks and brush by covering them with a blanket, foam camping pads or cardboard splints.

Using the Litter Shield

The CMC Litter Shield can be inverted and placed in the litter for storage or transportation. Before placing the patient in the litter, fold the litter shield out of the way over the head-end of the litter. If necessary, remove it completely from the litter. After the patient is tied in, rotate the shield into position. Secure the litter shield straps around the rail. The shield's strength relies on the three-point attachment to the litter.

If greater access to the patient is needed during the evacuation, release the side straps and flip the shield out of the way. It will hang from the pivot point until ready to be placed back into position. Practice putting the shield on and removing it quickly, so it can be done under rescue conditions without delays.



Since its inception, the CMC Litter Shield has prevented several patients from receiving injury during transport. In one case in Canada and another in Southern California, a large rock hit the shield hard enough to crack plastic but the patient was protected. Remember that when the shield deflects a rock, that rock will be bouncing somewhere else and the tender should be ready to dodge it in case it comes their way.

With a litter shield or a face shield, it is possible to develop a "greenhouse" effect that can make the patient very warm. If the patient is in a protected position, lift the shield away from the face to reduce this effect. As mentioned previously, try to position the head of the litter out of direct sunlight or cover the shield with a cloth or bandana.

CONCLUSION

When patient packaging has been completed, the care and safety of the patient is entirely in the hands of the rescuers. A well-packaged patient will be comfortable, secure, protected from the elements and protected from aggravating any existing injuries.

PART
03
Basic Skills

CHAPTER
13
Litters & Litter Rigging

TERMINAL LEARNING OBJECTIVE

The student will be able to describe the construction, materials, and uses of rope rescue software.

ENABLING LEARNING OBJECTIVES

1. Describe the types of rescue litters
2. Demonstrate how to properly attach a commercial litter harness for a high angle evacuation
3. Demonstrate how to properly attach a commercial litter harness for a low angle evacuation

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.2.20

In this chapter we cover the different types of litters and accessories, plus how to set up a litter for an evacuation. Techniques for litter evacuations will be covered in (see Chapter 26 High Angle Litter Evacuations).

LITTER TYPES

Basket Litter

Often referred to as a Stokes litter, the military-type steel basket litter provides the roll cage like protection needed for the patient during rope rescue operations. Modern commercial versions are available with stainless steel or titanium frames. Titanium litters are as strong as steel but weigh less than half as much. The lightweight litters with the flat metal straps are fine for disaster work and mass casualty, but the straps bend easily and might possibly push up into the patient's back, injuring them.

Basket litters are available in tapered and rectangular shapes. All backboards will fit, and there is room between the legs for an oxygen bottle or other adjuncts. Two-piece models allow the litter to be nested for storage in a smaller space or for ease of carrying when backpacking into the field. Confined space litters are narrower to fit through tighter locations but most still accept a full-size backboard. Extra wide litters are also available.

Basket litters usually come with a wood or plastic back piece and a mesh liner to protect the patient. With the litters we use in class, we pull out the back piece and liner and install a litter insert.

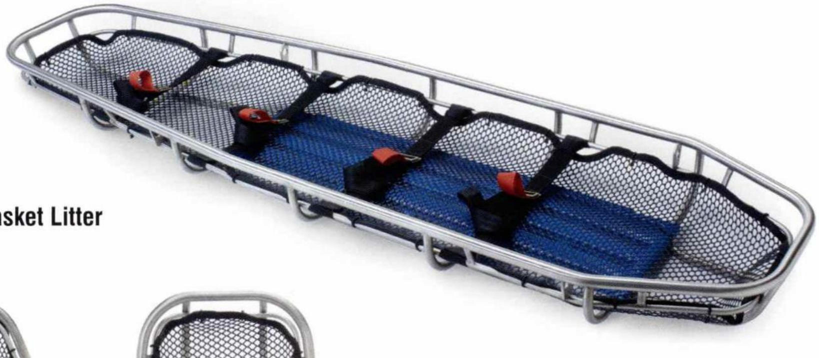


Figure 13-1: Modern Basket Litter

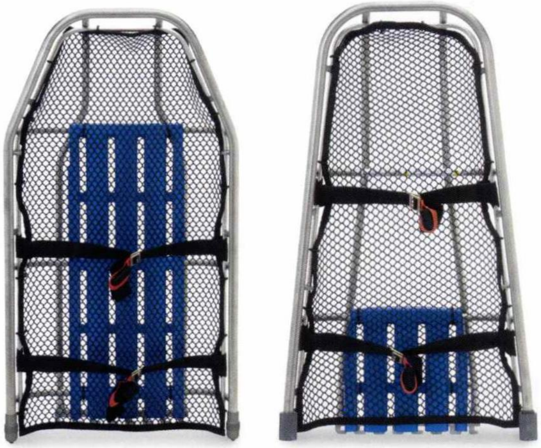


Figure 13-2: Two-Piece Litter

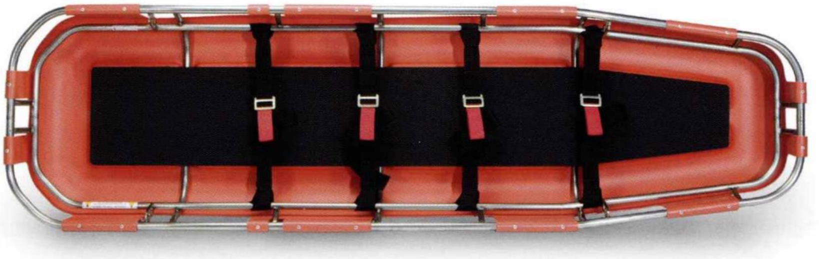


Figure 13-3: Plastic Litter with Full Frame

Plastic Litters

Plastic litters come in two basic types, those with a metal frame, which provides the strength for rope rescue operations, and those with just a metal top rail that, while suitable for snow operations and light load applications, are generally not suitable for rope rescue operations. A leading manufacturer of the latter type told us that their litters are not tested for the twisting, bending and side loading possible in a difficult evacuation. If there is a choice, use the metal basket litter or a plastic litter with a metal frame.

Plastic litters do provide great patient protection if the litter will be in contact with surfaces that are wet, brushy or debris filled. Look for the models that have good access to the top rail and a lower rail for attaching the patient tie-in. The frame should extend under the litter, either on the inside or outside, to provide the rigidity needed for rope rescue.

Semi-Rigid Litters

The Sked® Stretcher popularized the use of semi-rigid litters. The term semi-rigid refers to the Sked's ability to roll up into a compact size for easy storage and transport. When unrolled and folded around the patient, the Sked becomes rigid, but not quite as much as the metal frame litters. The lack of a rail to grip makes it difficult to use for a horizontal litter position in an evacuation.

The Sked Stretcher comes in several variations, depending on whether the primary use is for haz-mat or confined space operations. Extrication stretchers such as the CMC Drag-N-Lift Harness, Half-Sked Patient Drag, Spec Pak Patient Extrication System and the LSP Half-Back are used for removing patients from difficult locations such as during a confined space rescue. Some models provide spine protection, some hoisting capability, and some both.

Because of their tight fit around the patient, these litters work well for sliding a patient through pipes and ducts. They are designed for either horizontal or vertical lifts and some include built in patient tie-in systems.

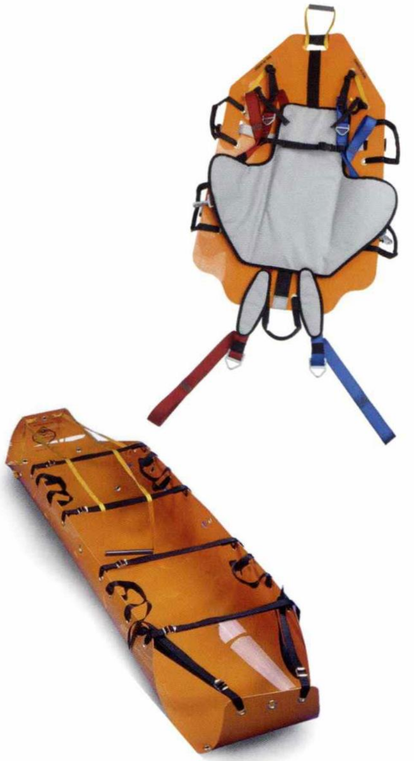


Figure 13-4: CMC Drag-N-Lift Harness™ and Sked® Stretcher

LITTER STRENGTH

How strong is that litter? Is that litter rated? The original military specification for litters included a performance requirement. The litter was suspended at the four corners and a 2,500 lbf (11 kN) load was placed in the litter. A minimum amount of deformation under load and remaining after the load was permitted.

The committee responsible for NFPA 1983 used the ASTM F2821 Standard Test Methods for Basket Type Rescue Litters and added performance requirements to allow the certification of litters to that NFPA standard. Litters are tested by suspending them in the manner most often used and then the load is placed on the litter through a plate in the bottom. The performance requirement looks at the deformation rather than trying to fail the litter.

LITTER ACCESSORIES

A variety of litter accessories have been developed to make patient transport safer and more comfortable, to make litter handling easier and to protect the rescuer. We will provide a brief overview here. Other chapters will cover the use of specific accessories.

Litter Insert

Many years ago, Yosemite Search and Rescue replaced the wire mesh in their basket litter with a nylon insert. The result was a more comfortable bed and better protection for the patient. The wire mesh often became a nuisance as sections eventually broke, leaving wire ends to stab the rescuer and patient. Several models of inserts are now commercially available.

Most of the inserts are "sewn" onto the litter rail with cord. This essentially makes the insert part of the litter. The CMC Litter Insert uses a system of straps, allowing fast removal and installation. Not only does it work with a split-apart litter, but it also helps hold the litter together. Because the insert is removable, it is also helpful when the litter is stored on the outside of the rescue truck and the nylon insert can be stored inside, away from exposure to the elements.

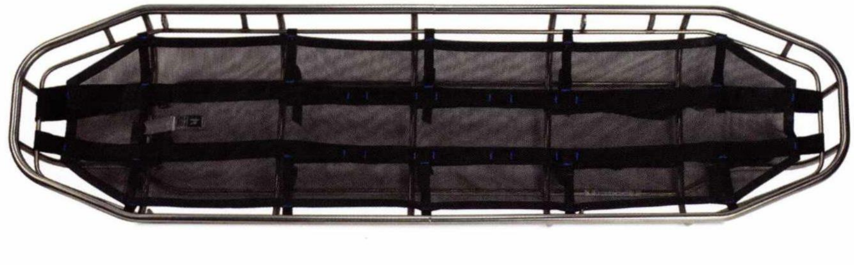


Figure 13-5: CMC Litter Insert

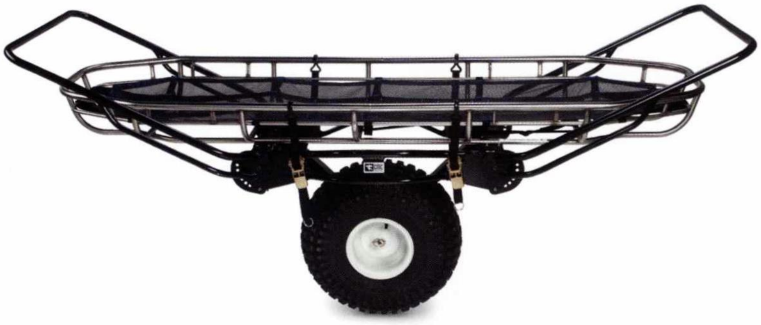
Inserts are available with solid or mesh material. A solid litter bed is warmer, but the mesh provides better drainage, air circulation and, if not too dense, lets the rescuer see through the litter when it is empty. An empty litter with a solid insert tends to float and spin when lowered out of a helicopter. The mesh may reduce this problem to a certain extent, although other factors have a much greater influence.

Litter Shield

A litter shield provides better protection to the patient than a helmet and goggles and is often more comfortable (see Using the Litter Shield on page 132).

Litter Wheel

Russ Anderson with Sierra Madre Search & Rescue produced an early, if not the first, commercial wheel for litters. It featured a large ATV tire which helped with balance and at low pressure, softened the ride. While the Russ Anderson wheel is no longer available, there are several others on the market. A litter wheel supports the weight of the litter and the tenders provide movement and balance. Today's versions have ATV or mountain bike wheels, some with handles and some with brakes.



Mule II Litter Wheel

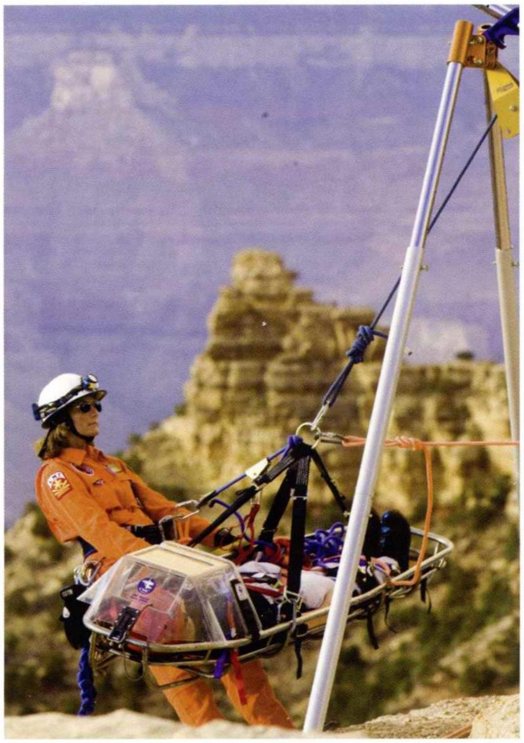
Figure 13-6: Litter Wheel

Litter Harness

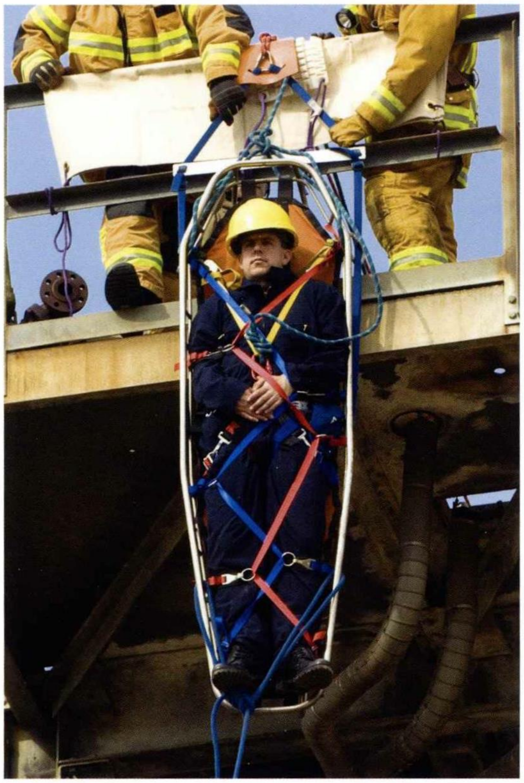
A litter harness connects the main line and belay line with the litter. While a rope could be tied directly to the litter rail, a harness can be adjusted for patient comfort or for negotiating a difficult edge. Commercial litter harnesses provide quick attachment to the litter and ease of adjustability. An improvised harness tied out of web offers more flexibility than tying the rescue ropes directly to the litter, particularly when the litter is in a horizontal orientation.

There are two primary types based on the orientation of the litter. One type, sometimes called a litter spider, attaches to the top railing and holds the litter in a horizontal position. The second holds the litter in line with the rope orientation. Sometimes called a low angle harness, it attaches at the head of the litter along the sides or both.

The functional advantage of a good harness for a horizontal litter is the ability to adjust the legs to level the patient. In most cases, start with the legs adjusted as short as possible. Keeping the legs short makes edge transitions easier and, if necessary, allows the litter to fit



Litter in Horizontal Orientation



Litter in Vertical Orientation

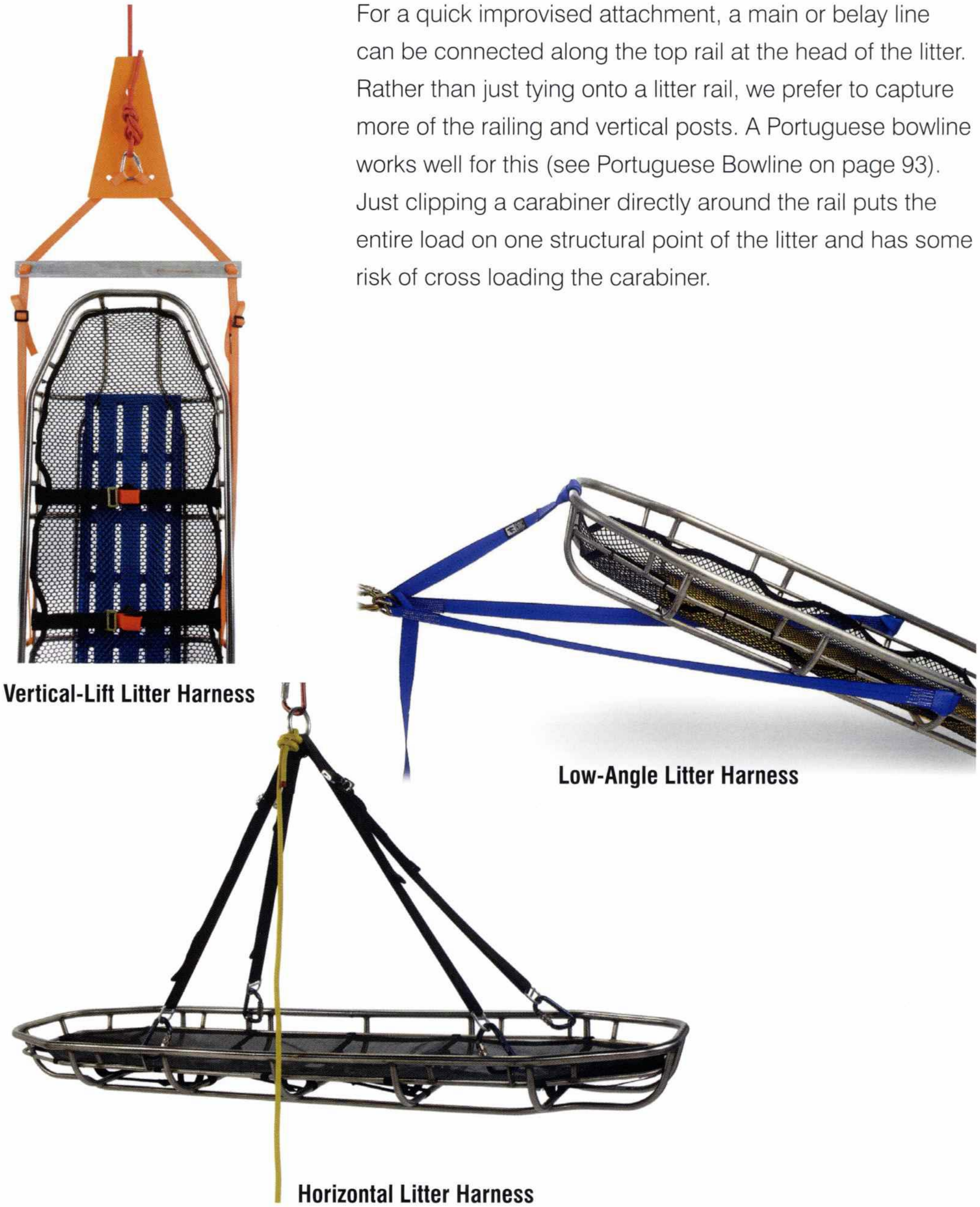
through small spaces, such as windows or helicopter doors. When the litter is loaded, the legs can be lengthened to place the patient in a level or slightly foot-low position.

While the most familiar evacuation using the horizontal litter orientation is the vertical evacuation, it also works very well for steep slopes. On the vertical or near vertical, a single tender pushes the litter away from the surface with their feet. On a less steep angle, two tenders can be used to hold the litter away from the slope. The outside legs of the litter harness can be lengthened to keep the patient in a level position. As a round edge is reached, the tenders can continue to lengthen the legs to maintain a level position.

When the tenders on a litter carryout started up a steep slope, a belay was attached to the front of the litter. As the angle increased, a mechanical advantage was added to pull the litter and tenders up the slope, thus the low angle litter harness name. Other teams working in confined spaces, either industrial or natural, used the narrow profile of the inline litter orientation for vertical evacuations.

Some designs, such as the CMC Low-Angle Litter Harness and the CMC Vertical-Lift Litter Harness, attach at the waist of the litter and run the webbing toward the front. This design allows the harness to pivot when coming out of a window or going over a 90° building or cliff edge. See Chapter 26 and Chapter 27 for details on how to use this system.

For a quick improvised attachment, a main or belay line can be connected along the top rail at the head of the litter. Rather than just tying onto a litter rail, we prefer to capture more of the railing and vertical posts. A Portuguese bowline works well for this (see Portuguese Bowline on page 93). Just clipping a carabiner directly around the rail puts the entire load on one structural point of the litter and has some risk of cross loading the carabiner.



Vertical-Lift Litter Harness

Low-Angle Litter Harness

Horizontal Litter Harness

Figure 13-7: Examples of Litter Harness Types

Notes

PART
04
Rescue Systems

CHAPTER
14
Twin-Tension Systems

LEGEND: Anchor Grip Load

TERMINAL LEARNING OBJECTIVE

The student will construct and operate a twin-tension system using multi-purpose devices.

ENABLING LEARNING OBJECTIVES

1. Describe the difference between a twin-tension system and a main/belay system.
2. Demonstrate how to properly operate a lowering using a twin-tension system.
3. Demonstrate how to properly operate a twin-tension mechanical advantage system.
4. Demonstrate operating as a tailer in a twin-tension system.
5. Demonstrate assisting in the operation of a raising system

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.1.1 | 5.2.9 | 5.2.10 | 5.2.11 | 5.2.13 | 5.2.14 | 5.2.15 | 5.2.16 | 5.2.21 | 5.2.23

TWIN-TENSION SYSTEMS

Rescue systems in which both ropes have shared the load equally have been around for some time. One version of a lowering system ran both ropes through the same brake bar rack. Another method connected each rope to separate ends of the litter, allowing its position to be adjusted during an evolution.

With the advent of the MPD, Twin-Tension Systems have become popular again. Also called Dual Capability Two-Tension Rope Systems, "dual capability" stresses the absolute requirement that each side of the system must be individually capable of not only supporting the load, but also functioning as a belay, should one side fail.

Frequently used in Twin-Tension type systems, the tailer is a third person behind the CLUTCH, MPD or other lowering device to provide a backup to the operators and to make sure each rope moves at the same speed. Some consider the tailer an essential position and others do not seem to need it. The tailer can be positioned in front, facing the device operators, with the rope running around a second friction post or a change of direction at the main anchor.

Advantages to the Twin-Tension System

- With half the load on each rope, a failure of one line transfers less of the load to the other line; as opposed to a main/belay system which would transfer 100 percent of the load, creating a higher impact force on the belay and a longer stopping distance.
- Testing reported at the International Technical Rescue Symposium demonstrated that equally loaded lines had a greater resistance to cutting over an edge than a main/belay system.
- Rigging devices for each rope can be the same, reducing the equipment and training needed.
- Each anchor is exposed to a lower load as the two anchors share the total weight. Yet each anchor must be constructed to support the entire load should a failure occur on one side or the other.
- In a main/belay system, the belay rope with less tension tends to drag on the surface, possibly knocking rocks down toward those at the end of the rope.
- The load on each anchor system is less. In the event of the failure of one line, the impact force on the remaining anchor is approximately half.

Disadvantages to the Twin-Tension System

- If systems cannot be close together, it can be difficult to keep tension equal. This is a concern on a raising if one team is trying to pull the full load, but half the haul team is on the other rope.

TWIN-TENSION SYSTEM EXAMPLES

The following scenarios are examples of how a Twin-Tension System could be rigged. The CLUTCH is used in these examples but other auto-stop devices such as the MPD also work well. Systems employing other descent control devices, and pulley/Prusik based M/A systems, can also be used in Twin-Tension Systems.

Scenario 1

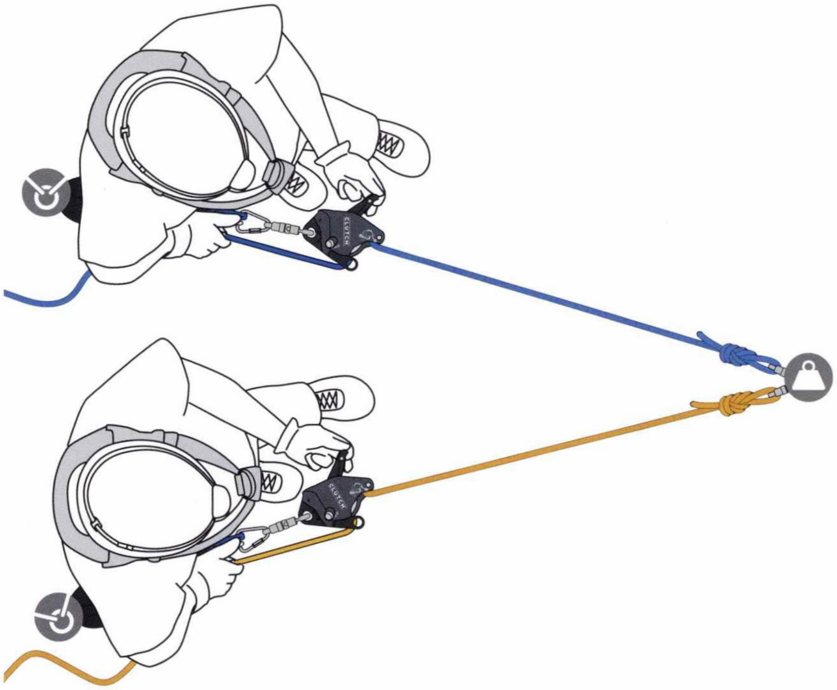


Figure 14-1: Senario 1 - Two operators, each operating the CLUTCH handle and rope tail

The CLUTCH is rigged to two individual anchors with two operators, each operating the CLUTCH handle and rope tail. As the load, which includes a rescuer and the occupied litter, approaches the edge, the load that the CLUTCH sees is relatively light to due to the fact that the load is not yet fully supported by the rope system. (At this stage of the lower, the edge transition, it may be more efficient to use one slack and one tension line with the CLUTCH to better payout and manage the rope.)

As soon as the litter is over the edge, the operators move from one slack and one tension line to a Twin-Tension System. Sharing the load is evenly divided between the two devices. The challenge in this scenario comes from coordinating the lower between the two operators. Watching the rate of movement of each line and keeping them even will balance the load between the two lines.

Scenario 2

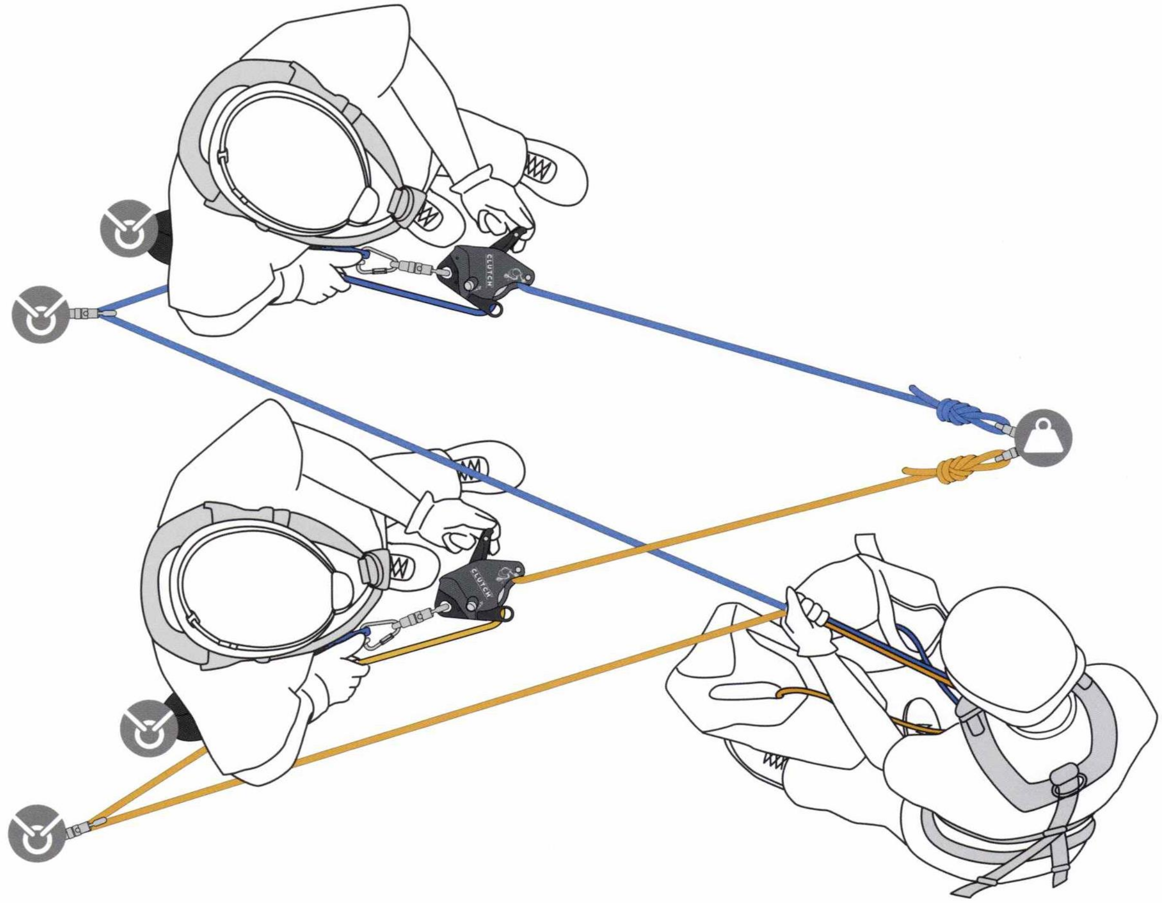


Figure 14-2: Senario 2 - Three operators, one managing the rope tails

If a third operator is available, the team can reduce the risk profile by adding a tailer to the lowering system. In this case, a single rescuer can manage both tails from each CLUTCH device and serve as backup to the CLUTCH handle operator. The tail is redirected to a center location. The tailer helps keep both lines moving at the same speed. If the CLUTCH operator experiences issues with controlling the speed of the lower, the tailer serves as risk mitigator in the operation. The tailer can stop the lower by holding firm on both rope tails.

Scenario 3

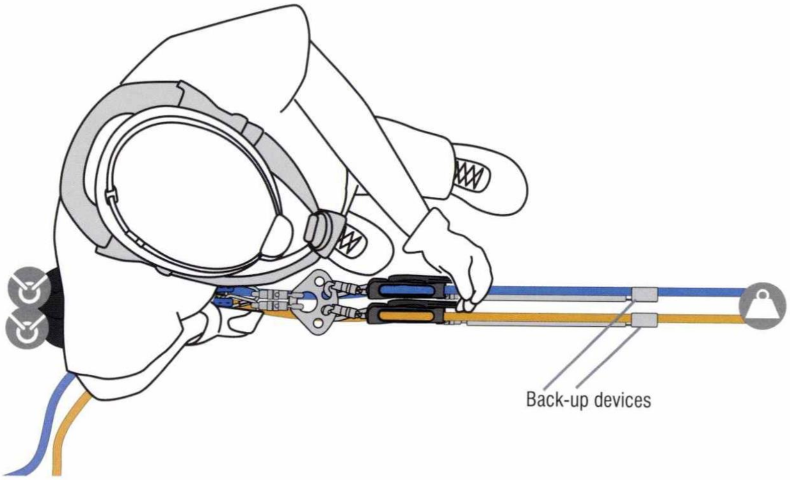


Figure 14-3: Senario 3 - One operator operating both CLUTCHES

In this third rigging scenario the number of rescuers is limited. If anchoring is appropriate and gear is available, the Double CLUTCH TTRS can be used to replace people with gear. Two CLUTCH units are rigged so they can be controlled by a single operator. We call this the Double CLUTCH.

A back up device and shock absorber designed for a two-person load is connected via carabiner to each CLUTCH becket and installed on the tension side of the CLUTCH. One operator controls both CLUTCH handles and both rope tails. The backup device serves as an unattended belay device, i.e. a backup tailer.

Note: There could be circumstances, in less than vertical operations, when the operator fails to control the speed of the lower, yet the backup devices have not reached trigger velocity.

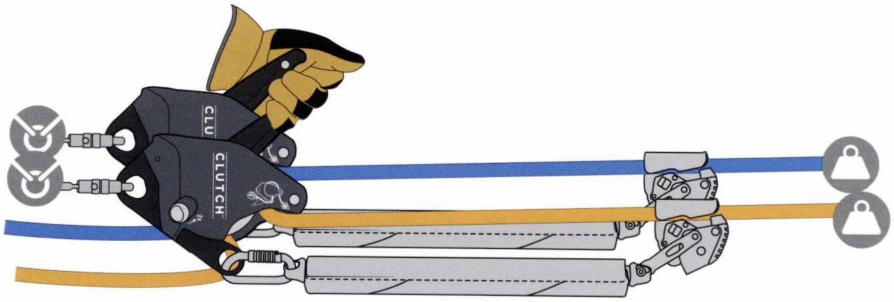


Figure 14-4: Double CLUTCH TTRS with back-up devices

Scenario 4

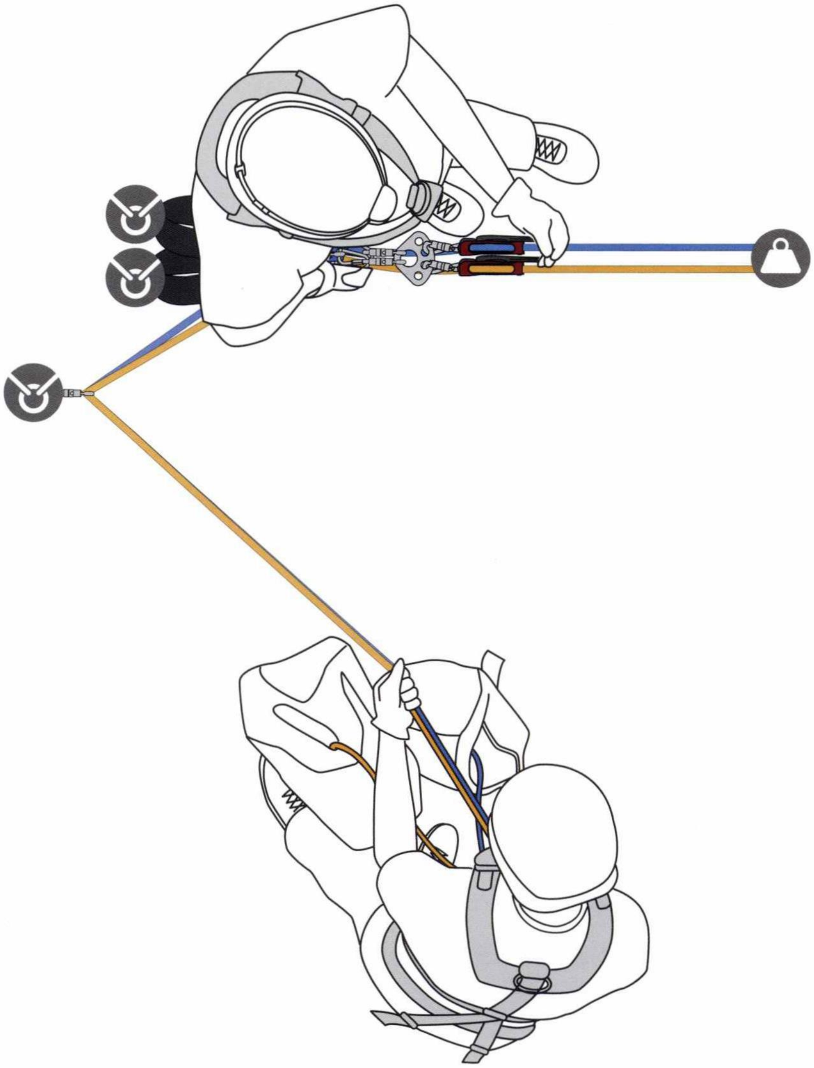


Figure 14-5: Senario 4 - Two operators, one operator operating both CLUTCHES and one managing the rope tails

To improve control when lowering by rigging the Double CLUTCH with a single operator, a second rescuer can be added as tailer to monitor the system with both rope tails in hand. Because each person can see and feel the ropes in service, this rigging scenario also promotes better shared tension at each CLUTCH. In all cases, a confident and properly trained operator is the best defense against an uncontrolled lower.

On a raising, there is a choice of how to organize the haul team: half of the team on each rope or the full team pulling both ropes together. The latter works well for keeping the tension on both lines equal. However, it has the typical haul team issue: The effectiveness of each person decreases the farther back in the line they are positioned. Splitting the haul team into two, is more efficient, but attention must be paid to keep the tension (rate of travel) on each line the same.

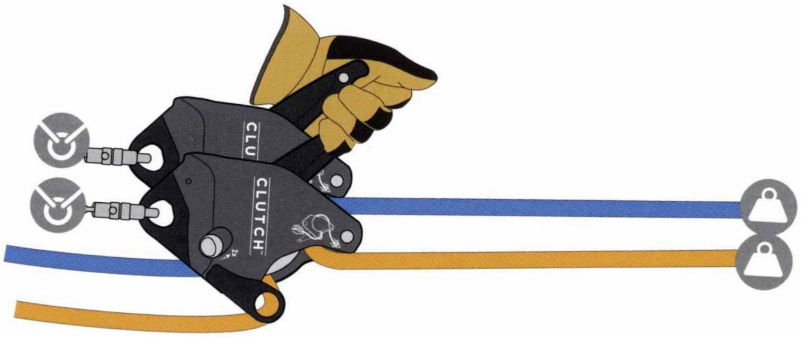
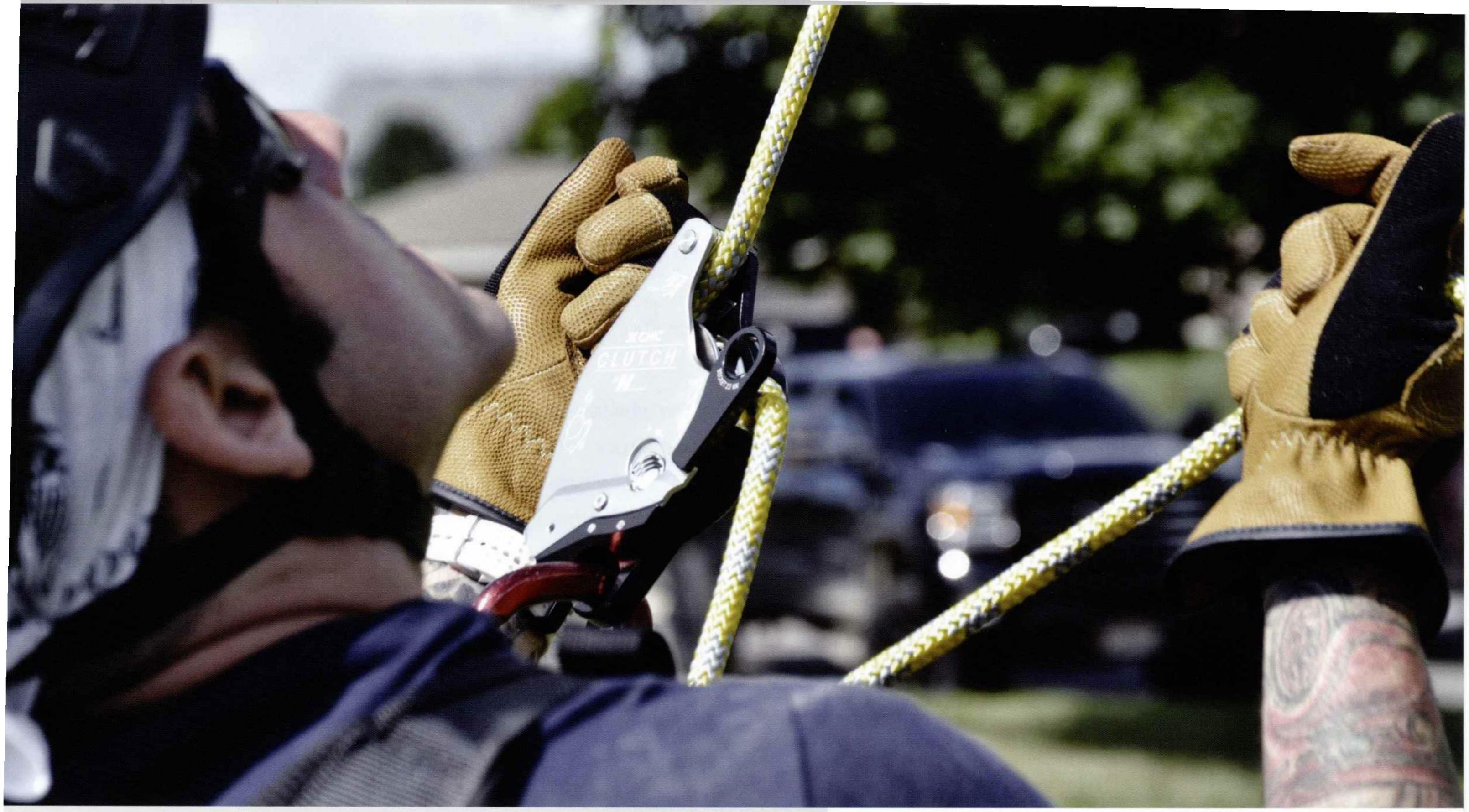


Figure 14-6: Double CLUTCH TTRS

SUGGESTIONS FOR TWIN-TENSION SYSTEM EFFICIENCY

- Watch the movement of the haul pulleys to keep loads even
- If space allows, pull both ropes together to keep tension even
- Pulling each rope separately is more efficient as the last few pullers in any haul system do not contribute as much as those in the front.
- The tailer keeps each side moving together while lowering

Notes



PART
04
Rescue Systems

CHAPTER
15
Belay Systems

TERMINAL LEARNING OBJECTIVE

The student will construct and operate a belay system using a mechanical belay device and with the Tandem Prusik Belay.

ENABLING LEARNING OBJECTIVES

1. Demonstrate how to properly operate a lowering and raising belay using an MPD
2. Demonstrate how to properly operate a lowering and raising Tandem Prusik Belay
3. Describe the difference between a tensioned and non-tensioned belay

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.2.9 | 5.2.10 | 5.2.11

LEGEND: Anchor Grip Load

Whenever rescuers or subjects are placed on a rope system, it is important to reduce their risk as much as possible. Because the possibility of a system failure exists, it is prudent to provide a safety backup or belay system. The belay system consists of a second rope attached to a separate anchor. Current belay systems use either knots (soft) or mechanical (hard) devices to grab the belay rope.

In Chapter 20 on system analysis we talk about the whistle test, which is an evaluation of what happens if the system operator lets go of the rope. For the belay system, this also includes the failure of the operator to react. Selection of a belay system should include its ability to catch a falling load independent of any action by the operator. A Munter hitch, a Brake Bar Rack or a Figure 8 descender are examples of belays that require a positive action by the operator.

The most common knot-based system is the Tandem Prusik belay based on a pair of Prusik hitches.

Advantages:

- Handles high-impact loads effectively
- Lighter in weight than a mechanical belay device
- Prusik loops have multiple uses
- A Prusik hitch adapts to a wide range of rope diameters
- Automatic activation – passes the whistle test

Disadvantages:

- Automatic activation is dependent on the hand and the relative diameter of the Prusik cord as well as being properly set and dressed
- Automatic activation is dependent on the angle that the rope exits the Prusik hitch
- User skill required to minimize slack in the system
- Should be used with a load release strap or load release hitch

The CLUTCH, MPD, and 540° Rescue Belay are examples of devices designed for belaying rescue systems. Other devices, such as the Petzl I'D, may be suitable if the manufacturer's cautions are heeded.

Advantages:

- Handles high-impact loads effectively
- Simple and easy to rig and to operate
- CLUTCH and MPD can be used as a pulley and ratchet for a raising M/A system
- Integral load release—no need for a load release hitch in system
- Automatic activation—passes the whistle test
- May require less training than knot-based belay systems

Disadvantages:

- Some devices require smoother sheath ropes to prevent locking up
- Greater weight
- Some devices are rope diameter specific

The performance of each system is also dependent on the elongation of the rope selected for the belay line. The elongation directly affects the impact force felt by the system. Too much elongation and the litter along with the tender and patient may crash into something before the belay arrests the fall. This is the greatest risk of injury to the rescuer.

ASTM F2436 is a test method for analyzing the performance of a belay system. By standardizing the test method different belay systems can be compared. The next question then is what performance criteria should a belay system meet, and the industry has yet to agree on a standard.

The British Columbia Council of Technical Rescue (BCCTR) created a test method several years ago in order to compare various belay devices and systems using dynamic (drop) tests. The parameters were drawn from a selected worst-case situation of a litter negotiating an edge during a lowering. The BCCTR was the basis that led to ASTM F2436, a test method for belay devices. That test method was used by NFPA 1983 which added the performance requirements of the BCCTR.

The BCCTR parameters include:

- 200 kg (440 lb) mass
- 1 m (3.28 ft) fall
- 3 m (9.84 ft) of 11 mm ($^7/_{16}$ in) rope
- Less than 1 m (3.28 ft) arrest distance
- Maximum 15 kN (3,375 lbf) peak impact force

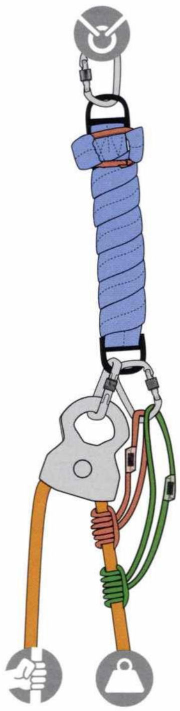


Figure 15-1: Tandem Prusik Raising Belay

TANDEM PRUSIK BELAY SYSTEMS

The Tandem Prusik belay system is set up the same way for either a raising or a lowering belay. Test sessions have indicated that tandem triple-wrap Prusik hitches using purpose-built 8 mm cord, as opposed to accessory cord, provide the best performance for holding large shock loads on $^7/_{16}$ and $^1/_2$ in (11 and 12.5 mm) ropes. For the most reliable performance, the belay should be set up so that the rope angles off to the side above the hitches. A load release strap, mariner's knot or load release hitch should always be used to attach the Prusik hitches to the anchor, allowing the load to be transferred if the Prusik hitches become locked up during a lowering.

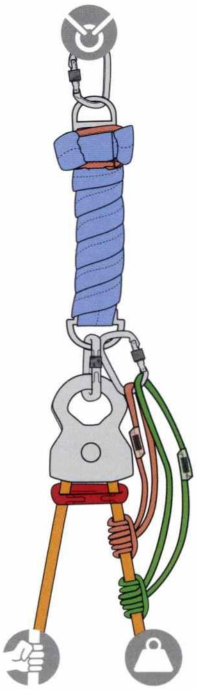
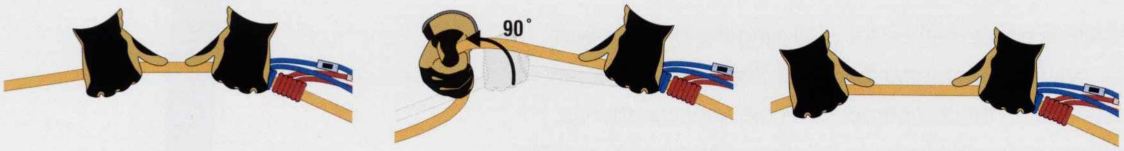


Figure 15-2: A small, oval carabiner can to help tend the Prusik hitches.

When raising, the belayer pulls the rope through the Prusik hitches at the same speed as the raising system. Keeping slack out of the belay system is important to minimize the

CMC PRO TIP

When operating a Tandem Prusik belay, rotate the hand to create a feel for the tension during a lowering. Keep the thumbs on top in the hitchhiker's position to keep them from getting hit if the belay activates.



distance the litter will fall before the belay catches. Running the belay line through a Prusik-minding pulley makes it much easier to pull the rope through the Prusik hitches. Be sure to pull at a 180° angle or add a carabiner to help manage the Prusik hitches.

For a lowering, the belayer tends the Prusik hitches so that they do not grab the belay line while the lower is under way. You should be able to feel a little bit of friction as you pull the belay line through the hitches. If the main line fails, the Prusik hitches will be pulled out of the belayer's hand as the system catches the load. If the Prusik hitches become too loose around the rope, there is a chance they might not grab quickly enough to catch a falling litter.

540°
RESCUE BELAY
LARGE

MECHANICAL BELAY DEVICES

The CLUTCH, MPD, and 540° Belay are self-locking mechanical devices that are certified to the NFPA standard for a belay device. They are easy to rig and operate. The CLUTCH and the MPD have the added advantage of acting as a pulley with a ratchet for raising, and as a belay device. Each device releases with a handle, eliminating the need for a load-release hitch.

Each device requires proper feeding of the rope, but the techniques are not any more difficult than required for properly managing a Tandem Prusik belay. They do provide a greater consistency than Prusik cord, which could vary between manufacturing lots or change performance parameters if the cord gets wet. In classes, we have found that the 540° Belay is easier to use with a polyester sheath rope. It is also easier to use if it is rigged in a vertical orientation than horizontal.

USING THE CLUTCH AS A BELAY DEVICE

Connect the CLUTCH to the system anchor. For a raising system, pull the rope through the CLUTCH, maintaining one hand on the rope at all times.

Belaying a Lowering System with the CLUTCH

For a tensioned belay of a lowering system, firmly grip the braking side of the rope and bring it back toward the anchor, parallel to the load end. Use the Control Handle to match the speed of the main line. **If there is a sudden change in speed or tension on the rope running through the CLUTCH, the belayer must immediately let go of the Control Handle (disengage) while maintaining a firm grip on the braking side of the rope to ensure the braking mechanism activates and arrests the load in the shortest distance possible.**

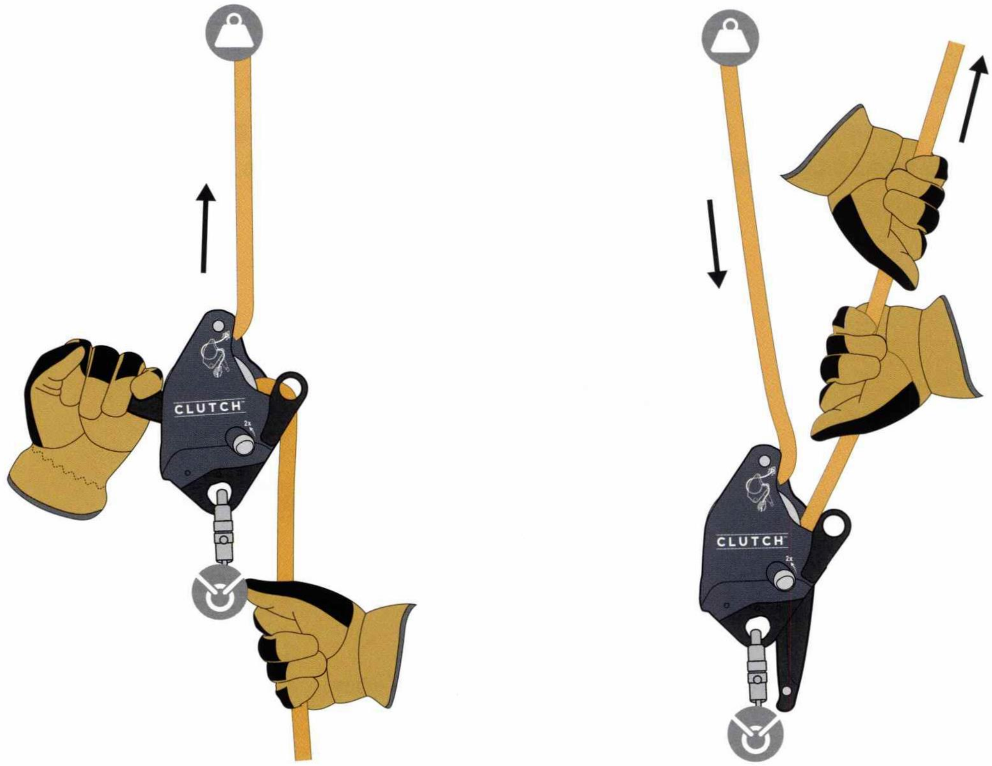


Figure 15-3: CLUTCH as lowering system belay (left) and as a raising system belay (right)

USING THE MPD AS A BELAY DEVICE

The MPD is designed to be used as a belay device to arrest a falling load should the main line fail.

Belaying a Lowering System with the MPD

With the MPD, belaying a lowering is essentially the same as operating a lowering system. The rope is bent back so the load is controlled by the V-groove. The Release Handle is opened all the way so that the belay is controlled with your hand on the rope and the friction in the V-groove.

While the MPD is an effective belay device capable of safely arresting a falling load, when used as a descent control device, you are manually overriding the belay function. This could result in increased stopping distances if not using proper technique. Therefore, in a twin tension lower it is imperative that the running end rope of the belay line be held back toward the anchor, maintaining the S-shaped bend as the rope runs through the MPD. If there is a sudden and rapid change in speed or tension on the line, **the belayer must let go of the release handle to ensure the braking mechanism activates and arrests the load in the shortest distance possible.**

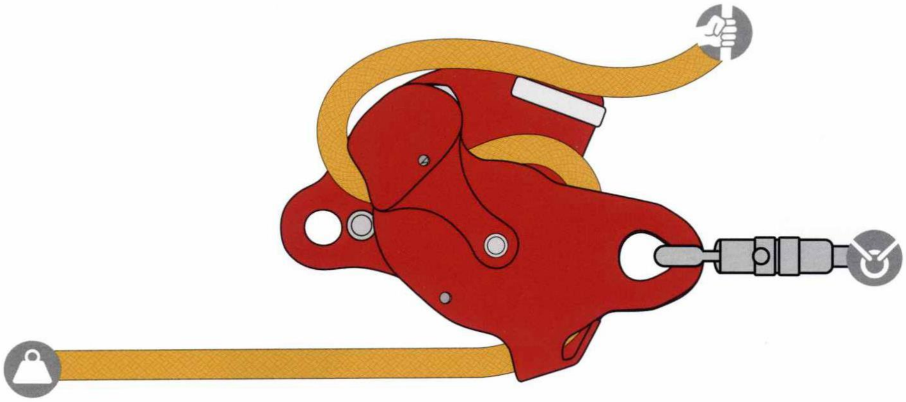


Figure 15-4: MPD as a lowering system belay

Belaying a Raising System

If the load is being raised, then the belay line can simply be pulled hand over hand through the MPD. However, if the distance the load has to be raised is greater than approximately 100 ft (30m), then consider converting the belay line into a simple 3:1 M/A system. This will make it easier to keep any slack out of the belay line and will assist with raising the load. For the final edge transition, convert back to a 1:1 and use only hand-tight tension on the belay line by pulling it in hand over hand.

If an MPD is used for both the main line and the belay line as haul systems, then should either of the rope systems fail, the other rope system serves as the belay and the potential arresting distance is minimized since both ropes will be pre-stretched.

OPERATIONAL CONSIDERATIONS

Set up the belay system close enough to the main system, so that a failure of the main line will not result in a pendulum movement by the load, but not so close that it would interfere with the operation of the main system. The haul team will always need a longer pull, and the less rope deployed for the belay means less drop if the belay takes the load. Using a different color rope for the belay helps to clearly distinguish each line when giving rope commands.

As a general rule, the belay line should not run through a change-of-direction pulley, particularly one attached to a high anchor point. If the change-of-direction anchor should fail, such as a collapsed tripod, then as the belay line moves into the fall line, a lot of slack is created resulting in a much longer fall, a higher impact force and possibly a pendulum.

You should be able to convert the belay line into a mechanical advantage system. With a Tandem Prusik belay using a pulley for a raising, or with the MPD, all that is needed is a second pulley and rope grab to turn the system into a 3:1 M/A.

Non-Tensioned Belay

Generally the load is on the main line and the belayer just keeps the slack out of the belay line. This allows the main line to have primary control of the system, particularly when lowering. The tender needs to communicate only with the main line operator regarding the rate of descent.

Another consideration is that a line under load is more susceptible to damage from rockfall than a line that is not loaded. If the main line and belay line are running side by side, then it is possible for both to be hit by the same rock. If the loaded main line is cut, it is possible that the unloaded belay line will not be damaged and will be able to arrest the fall.

See Chapter 14 for Twin-Tension systems.

Notes

PART
04
Rescue Systems

CHAPTER
16
Lowering Systems

LEGEND: Anchor Grip Load

TERMINAL LEARNING OBJECTIVE

The student will construct and operate a lowering system using different types of friction devices.

ENABLING LEARNING OBJECTIVES

1. Demonstrate how to properly operate a lowering system using a brake bar rack
2. Demonstrate how to properly operate a lowering system using a 3D or Brake Bar Rack
3. Demonstrate how to properly operate a lowering system using an MPD

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.2.13 | 5.2.14

The lowering system is the most basic system to set up and operate. Given a choice, lowering to the bottom is always preferred over raising to the top. The systems are simpler and the ride is smoother than a raising system, thus requiring fewer personnel to operate. The lowering system can be used with a litter, a rescuer assisting the subject and, if appropriate, the subject alone.

A lowering system consists of a braking device connected to an anchor. Once the most common device, the Brake Bar Rack is quickly being replaced by the MPD with the latter's ability to lower and then raise without changing equipment. The MPD also acts as a belay device, if needed.

The CMC 3D and the Conterra SCARAB® have the friction range of a Brake Bar Rack but are closer to the size and weight of a Figure 8 descender. Unlike the Figure 8, they do not twist the rope and both can be rigged without removing them from their carabiner.

Another device is the brake tube, a large L-shaped aluminum tube. Its ability to pass a knot through the device during the lowering makes it popular with teams that need to conduct a long lower. This advantage may offset its large size and weight. Since the rope wraps around the tube, it will put a lot of twist into the rope. It is not as easy to lock off or tie off as some of the other devices.

While the Figure 8 descender used to be in common use for lowering, teams were beginning to find that its ability to hold the weight of a litter, patient and tender was borderline. It also tended to cause a lot of twist in the rope, which would create a tangle feeding into the device. We recommend that all lowering systems have a belay, whether they involve a litter or not. For selection and operation of belay systems, see Chapter 15.

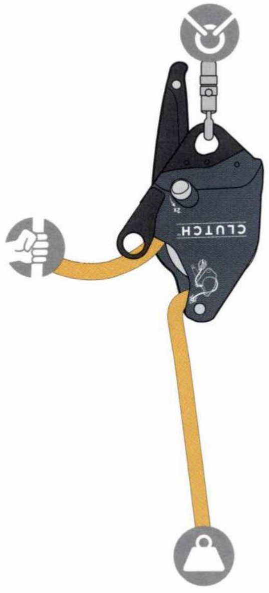


Figure 16-1:
Lowering System with the CLUTCH

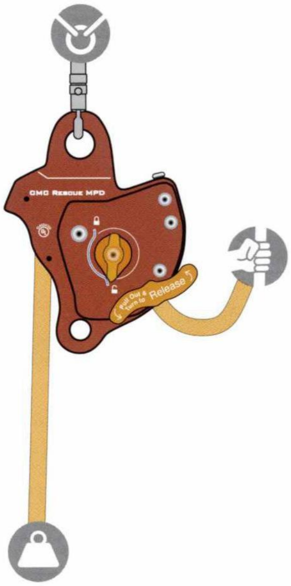


Figure 16-2:
Lowering System with the MPD

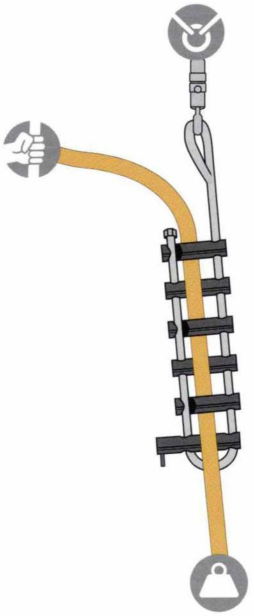
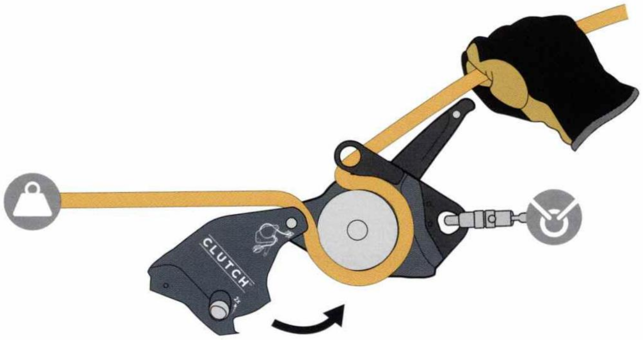


Figure 16-3:
Lowering System with a Brake Bar Rack

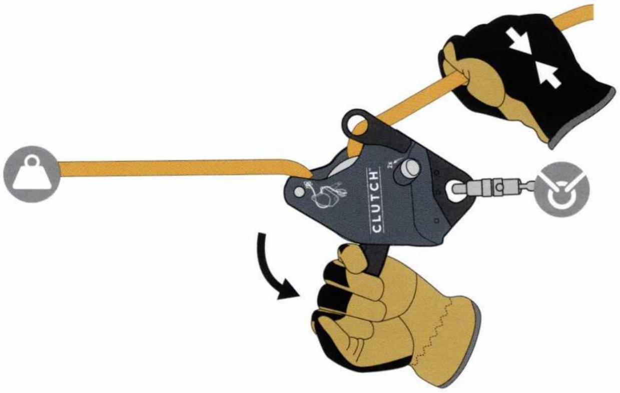
CLUTCH LOWERING SYSTEMS

Begin by attaching a CLUTCH to the anchor at each station. Load and function test the CLUTCH to confirm proper operation. The CLUTCH operator should stand slightly behind the CLUTCH, between the device and the anchor, to easily manipulate the rope tail and the control handle, while keeping a visual on the rope ends, the edge, and the opposing anchor station.



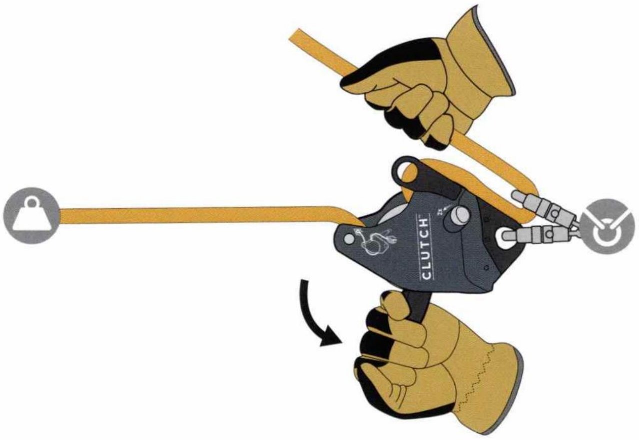
Preparing to Lower

Position the Control Handle in the Standby position until ready to lower.



To Lower

To lower, rotate the Control Handle to the Release position while keeping one hand on the rope entering the CLUTCH.



For Heavy Loads

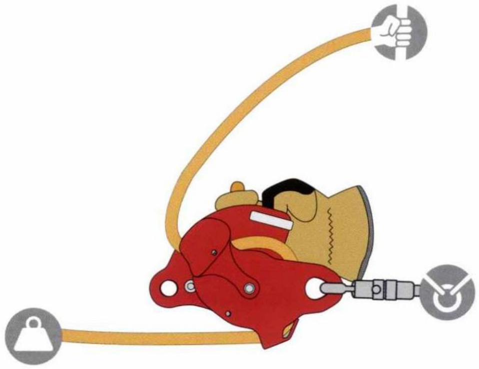
An extra carabiner may be used to increase friction on the free end of the rope for heavy load applications.

Figure 16-4: Lowering with the CLUTCH

The acceptable lowering speed depends on the weight of the load. For loads between 30 kg (66 lbs.) and 200 kg (440 lbs), limit the speed to below 2 m/s. For loads over 200 kg (440 lbs.), limit the speed to below 0.5 m/s. Speed can be judged by monitoring the flecking pattern on the rope passing through the device or by calculating target descent times for known distances.

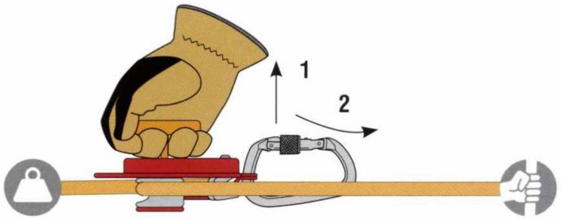
When lowering is complete, rotate the Control Handle to Stand By for short-term inactivity, or rotate the Control Handle to Stop for added security, this locks the rope in place and tucks the Control Handle out of the way. Consider tying-off the CLUTCH if leaving it unattended.

LOWERING WITH THE MPD



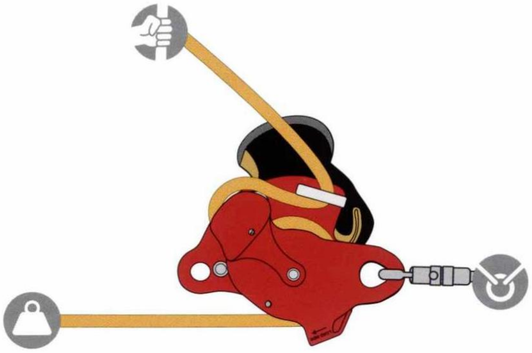
Preparing to Lower

Firmly grip the running end of the rope and apply friction over the fixed brake V-groove, bringing the rope back toward the anchor and parallel to the load end, creating an S-shaped bend in the rope.



To Lower

Disengage the Parking Brake, grasp the Release Handle, pull out to engage the release mechanism (1) and then rotate counterclockwise to initiate lower (2).



For Heavy Loads

Add additional friction by threading the rope over the Secondary Friction Post.

Figure 16-5: Lowering with the MPD

When used to control a descent, the MPD design allows for easy adjustment of the friction for the size of the load, rope type and environmental and terrain conditions. The speed of the descent is controlled by the friction of the rope applied against the fixed brake V-groove. Always start with the running end held firmly back toward the anchor parallel to the load end. Reduce the friction by varying the angle at which the running end enters the MPD. Maximum friction is applied when the secondary friction post is used.

To lower, firmly grip the running end of the rope and tightly hold it against the fixed brake V-groove, bringing it back toward the anchor and parallel to the load end, creating an S-shaped bend in the rope as it passes through the MPD. Pass the rope over the Secondary Friction Post for heavier loads if needed. Disengage the Parking Brake and then firmly grip the release handle. For the most comfortable hand operating position, before pulling outward on the handle, give a slight clockwise turn of your wrist, then pull out to engage the release mechanism. Begin lowering by rotating the handle slowly, counterclockwise, all the way to completely unseat the moving brake from the rope, controlling the rate primarily with friction on the fixed brake V-groove. Maintaining the S-bend in the rope will improve the function of the braking mechanism in the event it is needed, and will increase the service life of the moving brake, reducing the potential for rope creep through the device.

To stop lowering and lock the rope, disengage the Release Handle. Although there is a return spring to assist in disengaging the release handle, it is the user's responsibility to ensure that the handle is fully pushed in when not actively lowering. Always maintain a firm grip on the running end of the rope when the parking brake is not engaged.

USING THE 3D™

The CMC 3D is similar to many of the micro-racks that have been available for years with three significant differences. It is designed for loads, from the individual on rappel to full litter systems, and is UL classified general use. The locking center bar allows the 3D to be rigged from either side without popping the bars loose. It functions with rope diameters from 3/8 in up to 1/2 in (9.5 mm to 13 mm).

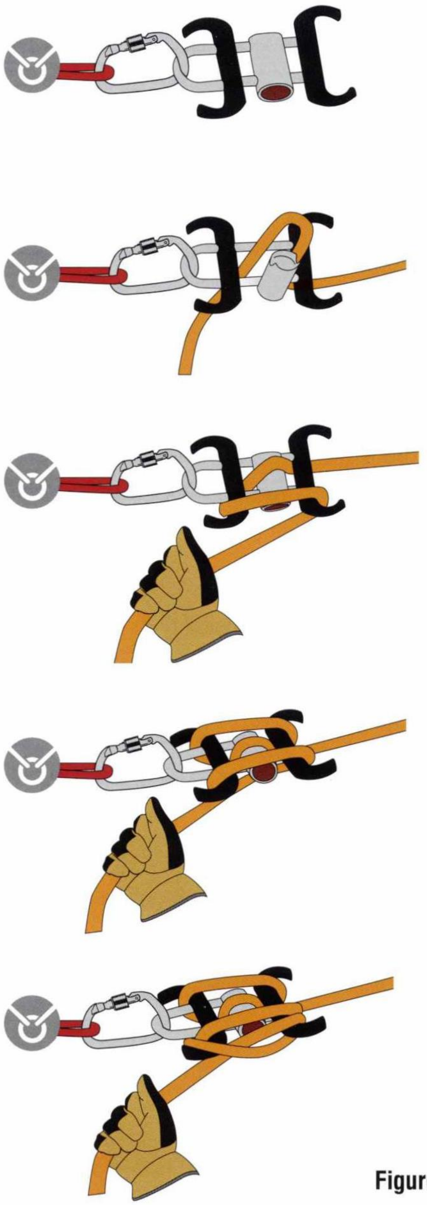
The 3D may be rigged while connected to your harness or to the anchor for the system. The following procedure is recommend by CMC.

Start by pushing in the red button on the center bar and rotating it up 90°. Run the rope over the top and push a loop down between the top and bottom bars. Close the center bar, verifying that it has locked into position.

For the start of a lowering or a rappel, wrap the rope around the horn on the bottom and then around the horn on the top bar as shown in the illustration.

To add friction for heavier loads, cross the rope over the 3D and wrap additional horns as shown in Step 5.

To tie off, cross the rope over the 3D and secure with a Half-Hitch around the top horn. See Step 6.



Step 1.

Push and hold red button to unlock.

Step 2.

Push center bar toward button and rotate.

Step 3.

Push bight of rope up between horns and rotate center bar back into lock position.

Step 4.

For rappel applications, or for lowering light to moderate loads, the rope should engage the bottom and top horns as shown.

Step 5.

For maximum friction, cross the rope over and engage the bottom and top horns on the opposite side of the descender. We recommend this reeve prior to tying off the descender.

Step 6.

To tie off, twist a half hitch around an upper horn as shown. For added security you may cross to the other side and add an additional half hitch.

Figure 16-6: Using the 3D

USING THE BRAKE BAR RACK

A popular descent control device used for systems is the Brake Bar Rack. The operation of any descent control device for a lowering system and for a rappel have a lot in common; the primary difference is that for a rappel, the rack connects to your harness and for a lowering brake, it connects to the anchor. Because the rack is used primarily for lowering, we cover its use here, but in many situations it may be the preferred rappel device. Using the Figure 8 descender is covered in Chapter 21.

If the rack was purchased pre-assembled, check to make sure it was assembled correctly. Are the bars rigged in alternate orientation? The bars on a J-frame Brake Bar Rack should pivot on the long side of the frame. The tie-off bar is an exception since it is not removed when rigging the rope. When adding or removing a bar, position it as close as possible to the open end of the rack and then give the frame a slight squeeze. This makes it easy to pop the bars on and off the frame.

Check the bars for sharp edges and check the security of the nut. When the bars are locked on the rack, they should slide easily when the rack is tilted up and down. If they do not, the sides of the rack can be bent closer together or farther apart until the bars slide easily. If the frame and bars were purchased separately, follow the manufacturer's instructions for assembly.

Figure 16-7 shows the parts of the rack and how it should be rigged. The rope wraps around the left side of the last bar and continues to the user's right hand, providing the maximum available friction. The bars should pivot on the long leg of the rack so that the bars not in use can fit down into the well.

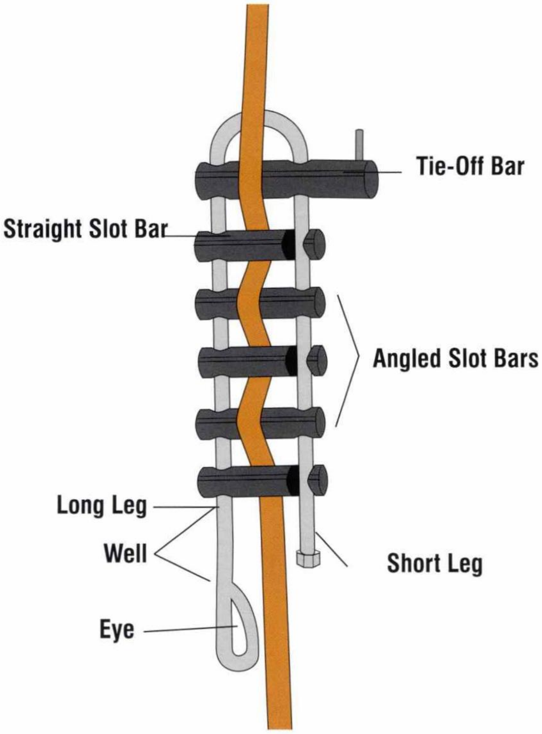


Figure 16-7: Parts of a Brake Bar Rack

The rack is more complicated than a Figure 8 descender, and one of the most frequent concerns voiced is the possibility of rigging it backward. If the rope runs on the slot side of the angled slot bars, the bars may stay in place until full weight is placed on the rack. The rope then pops all the bars off, allowing the rack and the rope to separate.

Most racks now have a straight slot bar as the second bar. A correctly rigged rope holds this bar against the frame. If the rope runs on the wrong side, the straight slot bar will flop loose, warning the user there is a problem before the rack is loaded.

Rigging the Rack

The Brake Bar Rack is left attached to the anchor while it is rigged, which prevents any chance of dropping it. The side of the rack attached to the eye (the long leg) should be toward the side or bottom when the rack is connected to the anchor. This provides the necessary clearance with the ground for the short leg of the rack to allow movement of the rope from side to side as you adjust the friction.

Rig the rack by placing the rope against the top bar on the side opposite of any notch. Push the rope between the frame sides, move the second bar onto the rack and then pull the rope against the bar. Continue down the rack, allowing the rope to weave in and out of the bars.

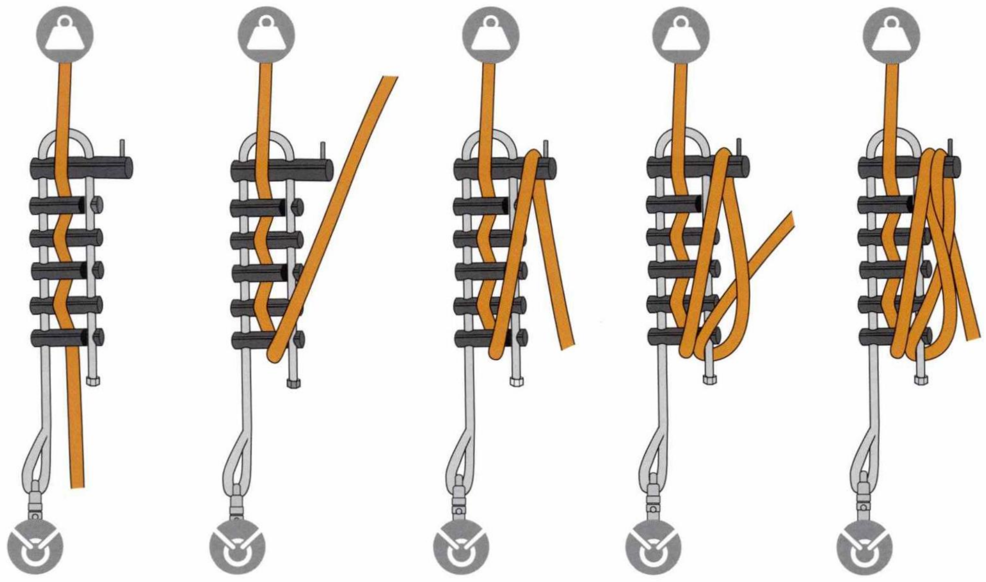


Figure 16-8: Tying Off a Brake Bar Rack

Check the straight slot bar to make sure the rope holds it and the bar does not flop loosely. Then test load the rack to double check the rigging.

Always start the lowering with all the bars rigged before going over the edge. When the weight is fully on the rack, the bars can be adjusted as needed to maintain the desired rate of descent. This may require feeding the rope into the rack while starting over the edge but allows maximum friction. A general rule is never to use less than four bars. With three bars, the integrity of the system relies on only one bar. If the center of the three bars should fail, the rope will be released.

Controlling the Lowering

The primary control of the rate of descent is by sliding the bars together for a slower descent and apart for a quicker. The bars will move together as the rope runs through them, so must be held apart to maintain descent. For a right-handed person, the left hand spreads the bars as needed. The right hand holds the end of the rope and acts as a backup. It also allows control of the rack if you need to use the left hand to spread the upper bars or to remove or add bars.

If the bars are spread as far apart as they will go and there is still too much friction, remove a bar. It is safest to stop the lowering before working on the rack. By transferring the rope to the other side, the pressure will be off the lowest bar. It can then be slid toward the eye and popped free. This will give you more room to spread the remaining bars.

If you need extra friction, the rope can be run over the tie-off bar. To stop, push the bars together slowly. Jamming them together for a sudden stop may cause a dangerous bounce if there is a lot of rope between you and the anchor.

The Brake Bar Rack ties off by sliding the bars together and lifting the rope up and over the tie-off bar. Bring the rope down and with a twist, loop it over the end of the short leg. Then add another twist and loop it back up and over the tie-off bar. The process is similar to tying off a boat cleat (see Figure 16-8).

For Rappels

Since the rack uses two hands, this does not leave a hand free to operate a Prusik hitch self-belay. Since safety-conscious rescue teams require a second point of attachment to the rope on a single-line system, namely the self-belay, the Brake Bar Rack loses the advantage of controlling the descent by spreading the bars. One solution is to use the tactical rappel set up with the Prusik hitch below the rack (see The Tactical Rappel on page 228).

When rigging for a rappel, the short leg of the rack should be toward the user's brake hand. This allows room for the rope to be moved left or right when removing bars.

The weight of the rope below the rack acts just like the brake hand pulling down. This can make descending difficult and bars can be removed to allow the rappeller to descend. As you approach the bottom of the rappel, the weight of the rope below decreases and more friction is needed to keep the descent rate the same. Plan on stopping to add bars before the rappel becomes too fast or it becomes difficult to hold your weight.

Notes

PART
04
Rescue Systems

CHAPTER
17
Raising Systems & Mechanical Advantage

LEGEND: Anchor Grip Load

TERMINAL LEARNING OBJECTIVE

The student will define simple, compound and complex mechanical advantage systems and how to use them to raise a rescue load.

ENABLING LEARNING OBJECTIVES

1. Describe how a pulley creates mechanical advantage
2. Identify simple, compound and complex mechanical advantage systems and describe their key features
3. Construct and operate a simple 3:1, complex 5:1 and compound 9:1 mechanical advantage systems
4. Describe how to use a piggy back system
5. Assist in the operation of a raising system

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.1.1 | 5.2.15 | 5.2.16 | 5.2.17 | 5.2.18

Rope rescue is the capability to move a patient in the vertical environment, and for many, rope-based pulley systems are what come to mind. A team of rescuers pulling on a mechanical advantage system is the most common means of raising a litter, and we will go over this thoroughly. We will also introduce some other methods in use by rescue teams.

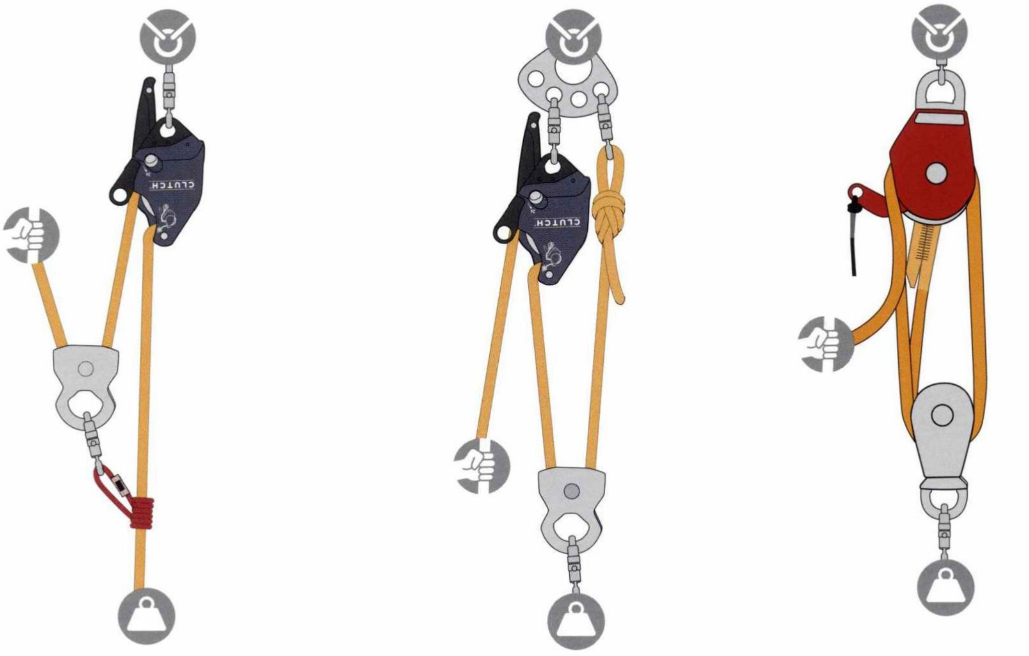
As with the lowering system in the previous chapter, the load may be a litter with a patient and one or more tenders, a patient supported by a rescuer or, if appropriate, just the subject alone. Raising systems are also used to return rescuers up to the side of the road when the slope is too steep to negotiate without assistance.

Pulleys and Mechanical Advantage (M/A)

A raising system can be as simple as a single rope attached to the load and pulled on by a team of people to a complex combination of pulleys that increase the mechanical advantage to the point where one person can raise a load much heavier than their own body weight.

Pulleys perform two distinct functions in a mechanical advantage system. If the pulley is attached to the anchor, it is called a *fixed* or *change-of-direction* pulley. Its function is to change the direction in which the rope is running. A *moving* or *mechanical advantage pulley* acts to increase the mechanical advantage of the system.

As the haul team pulls on the rope, the M/A pulley or pulleys will move toward the anchor, collapsing the system. The system is then reset by moving the M/A pulley away from the anchor, spreading the system out. The number of times that the system will need to be reset depends on the distance the load must be raised and the distance that the mechanical



3:1 Simple M/A System

2:1 Simple M/A System With a Change of Direction

4:1 Simple M/A System with Double Pulleys

Figure 17-1: Simple M/A Systems

advantage system can be extended. If the M/A pulley can be moved far enough to attach directly to the litter, then a reset would not be needed.

The ***ratchet***, sometimes called a ***progress capture device*** or ***PCD***, is a rope grab device that attaches to the anchor and holds the rope, so that the load will not lower when the pulling force is released from the system (see Figure 17-6c). This acts as a safety that prevents the litter from falling if the haul team unintentionally lets go of the rope. It also allows the haul team to release tension on the rope, so that the mechanical advantage system can be reset. A Prusik hitch, a CMC Ascender or a Rescucender can all be used as a ratchet. **Every raising system from a simple one-to-one pull on the rope to the most complex system should be protected by a ratchet.**

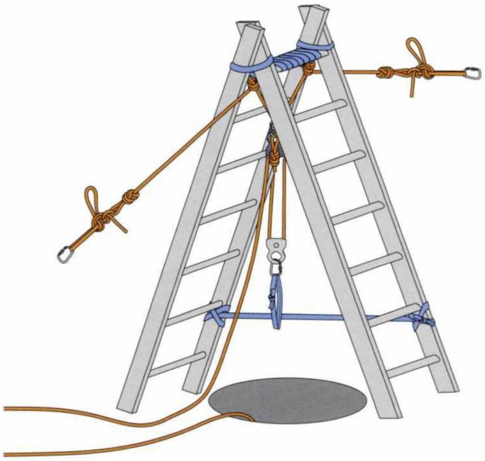


Figure 17-2: with a Simple M/A System

The CLUTCH or MPD can be used in place of the fixed pulley and ratchet. Combining both functions in the same device eliminates several pieces of gear, is a more efficient ratchet and allows immediate conversion to a lowering system. The Petzl I'D may also be used but lacks the pulley function with a corresponding decrease in efficiency.

By building systems using different combinations of M/A pulleys, fixed pulleys, rope, anchors and ratchets, we can design the right system for the specific evacuation we need to accomplish. Generally, using the lowest mechanical advantage needed to raise the load will result in the quickest rescue.

The simplest method of raising a load is just to pull on the rope. If you have the physical strength to exert a force of 100 lbf (0.5 kN), then you can lift a 100 lbf load. Adding additional rescuers to the haul team increases the amount that can be lifted. A one-to-one system is very smooth and does not require a reset. It does require a greater lifting force or more people pulling. Often a change-of-direction pulley is used to allow the haul team to pull in a more effective direction and tend the ratchet.

The primary disadvantage to this system is a matter of group dynamics. A haul team of 20 people does not respond as quickly or as accurately to commands as a team of three people. As a result, starting to pull takes longer and stopping is slower to accomplish.

This system works well on roadsides, particularly when rescue vehicles are blocking the road, resulting in a crowd of people available for the haul team. If managed well, the raising can be completed with a single pull, eliminating the need to stop and reset a mechanical advantage system.

Simple Pulley Systems

Simple mechanical advantage systems can be defined as systems in which all of the M/A pulleys are moving at the same speed as the load. The most common simple pulley system used for rescue is the 3:1, sometimes called a Z-rig because when it is set up, the rope is shaped like a large letter Z.

In theory, a 3:1 M/A system will increase your lifting force by three times. For example, a 100 lbf (0.5 kN) force will lift a 300 lbf (1.5 kN) load. Due to friction in the system, the realized mechanical advantage is always slightly lower. **It is very important to remember that the weight of the load includes all of the friction generated by the rope running over surfaces and edges.**

Other simple pulley systems are the 2:1 M/A, often called a *ladder rig* and the 4:1 M/A system, which is essentially the same but set up with double pulleys. These two are commonly used when connected to a high portable anchor for vertical retrieval from a confined space.

Compound Pulley Systems

Compound systems are created when a simple pulley system is pulling on another simple pulley system. By adding a 2:1 M/A system to the end of a 3:1 M/A system, you compound (or multiply) the mechanical advantage to 6:1. A 3:1 M/A system pulling on a 3:1 M/A system has a 9:1 mechanical advantage.

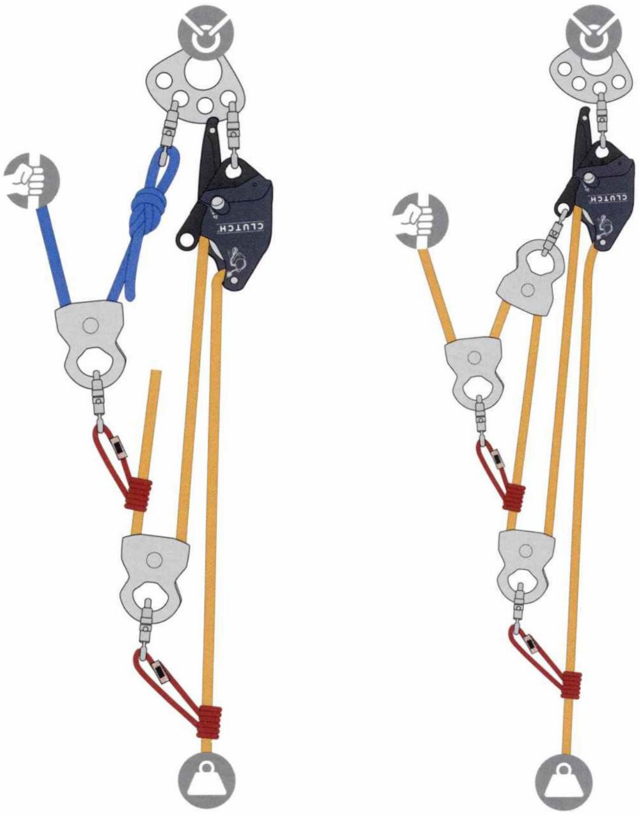


Figure 17-3: 6:1 and 9:1 Compound M/A Systems

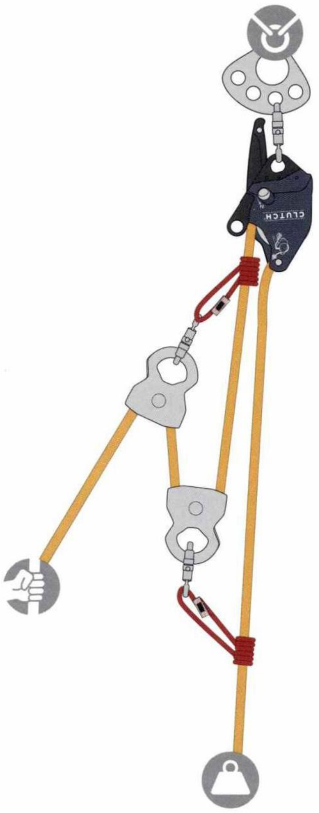


Figure 17-4: 5:1 Complex M/A System

Complex Pulley Systems

A system this is neither simple nor compound is a complex system, for example the 5:1 system in Figure 17-4.

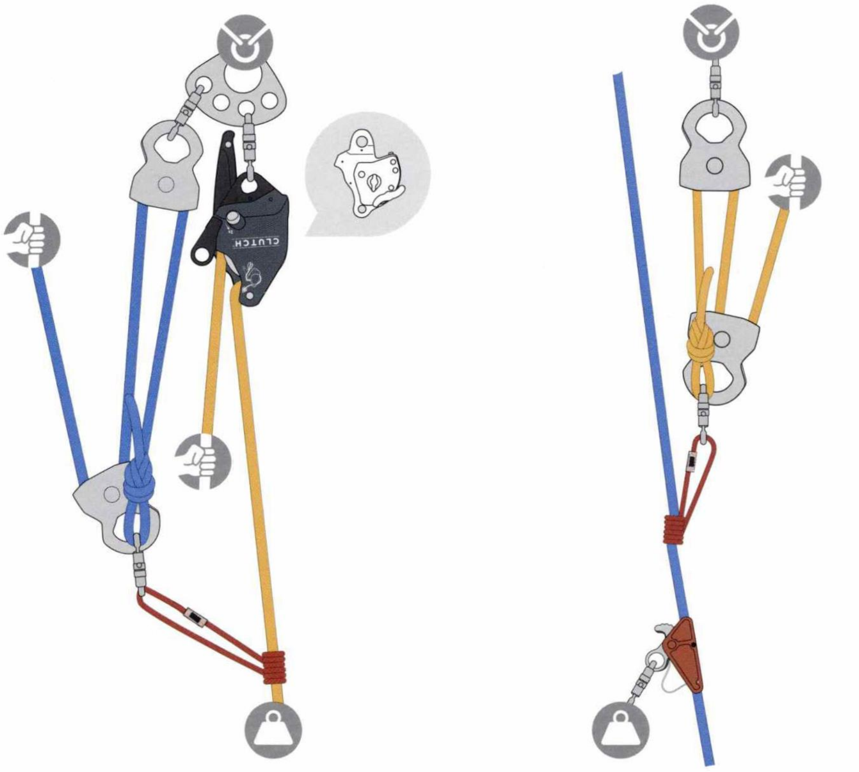
Piggyback Systems

A mechanical advantage system can be piggybacked onto the main line. The load is supported on the main line and held by a ratchet. A pre-rigged mechanical advantage system is then connected to the main line with a Prusik hitch. A piggyback lowering system can also be set up using a descent control device.

A disadvantage is the requirement for someone to tend the ratchet unless it can be placed in front of the M/A pulley. This would require an extension from the main anchor or a separate anchor for the ratchet.

This type of system can be very advantageous when the load needs to be raised and lowered back and forth a number of times. A ratchet device that also functions as a lowering brake makes this operation very efficient.

The piggyback system is also useful if the subject is already on a rope and you just need to pull up or lower to the ground. The piggyback system also works well for passing knots in both raising and lowering systems.



Piggyback with Ratchet in Back **Piggyback with Ratchet in Front**

Figure 17-5: Piggyback Systems

MECHANICAL ADVANTAGE SYSTEM CONSIDERATIONS

Several things happen when the mechanical advantage of the system is increased. First, as pulleys are added, friction in the system increases, and the difference between the theoretical mechanical advantage and the actual also increases.

- For every unit of length that the load is raised, the amount of rope that must be pulled through the system also increases. For a 3:1 M/A, 3 ft (90 cm) of rope must be pulled through the system to lift the load 1 ft (30 cm). For simple and compound systems the extra length of rope is proportional to the mechanical advantage but not for complex systems.
- Due to the pulleys moving towards each other in complex systems you pull less rope to gain the same mechanical advantage as a simple system. For example for a complex 5:1 you pull four feet (3.65m) of rope to move the load one foot (90 cm.) Complex MA systems also require less hardware to construct and the haul team pulls towards the load rather than away from it. That might be an advantage if the haul field is on a slope. The downside to complex systems is that you must move two different pulleys, in opposite directions to reset the systems.
- The subsystems of compound and complex systems collapse at different rates. This, plus the extra rope required, may result in the system having to be reset more frequently for the same overall length of raising.
- As the mechanical advantage system makes the haul team effectively stronger, it also reduces their feel for the load. Changes in the force required, particularly a hung up litter, may not be easily detected.
- If you use a Load Release Strap or a release knot to attach the ratchet to the anchor, you will be able to release tension on the ratchet. This would occur anytime you need to lower the rope but cannot pull the rope up first to take the tension off of the ratchet, such as when converting from a raising system to a lowering system.
- If the belayer is not strong enough to keep the slack out of the line, a mechanical advantage system can be used with the belay line. This will provide a tensioned belay but will slow down the operation of the belay, which should be taken into consideration. The conversion to a 3:1 system can also change a belay line into a raising main line if necessary.
- The haul team needs to be careful with the increased power in a mechanical advantage system to avoid pulling too hard. The additional force placed on the anchors and the equipment is not the only consideration. A 3:1 system pulls on the rope grab with a 2:1 advantage and in a compound 9:1 system this would be a 6:1 advantage. The added mechanical advantage gives a haul team the capability of cutting the rope if they are using a mechanical ascender for the rope grab, which is why we strongly recommend only using a Prusik hitch to attach the mechanical advantage pulley to the rope.
- With the right size cord, a Prusik hitch will slide when overloaded. Too small a diameter and the Prusik cord could lock up and then break. If at any time the haul team finds that

the effort to pull has greatly increased, they should stop and find out why. The load may have become stuck and continued pulling will lead to a system failure.

- Reducing friction is better than increasing the mechanical advantage or adding more people to the haul team. Any additional people required to haul on the main line increases the load on the rope, hardware and anchors. By reducing friction, you reduce the force on the anchors and equipment. Add edge rollers or Ultra-Pro Edge Protectors where the ropes bend around edges, or use change-of-direction pulleys to hold the ropes away from corners. Position any change-of-direction pulley to minimize the amount the rope bends when going through the pulley.
- Make the system as large as the working area and the length of your rope will allow. The farther you can pull the mechanical advantage pulley away from the anchor, the fewer times you will have to stop and reset the system. The result is a smoother raising that will take less time. Try to keep the ropes going into and out of a mechanical advantage pulley as close to parallel as possible for maximum pulley efficiency.

HAUL TEAM PERFORMANCE

Over the years we have conducted tests to see how much force could be exerted by a haul team pulling on a rope. An early test was a static pull done on a concrete surface using a $^1/_2$ in (12.5 mm) low-stretch rope. A Dillon dynamometer was used to measure the maximum force exerted. With gloved hands, two people were able to pull 450 lbf (2 kN). Next we tried attaching a Prusik to the rope and clipping it to the D-ring on the back of their harnesses. The same two people registered a pull of 900 lbf (4 kN).

More recent tests done in our classes show the average hauler pulls 50 to 70 lbf (0.22 to 0.31 kN) on the rope before asking for help or setting up a higher mechanical advantage. The higher forces noted above can be managed for short hauls, but the 50 to 70 lbf has proven to be a good average for sustained pulls. Even for a haul team that is trained to stop when the load increases from a possible hang-up, the reaction time delay causes a momentary increase in force that can cause a failure. The average maximum force seen in the tests for one person is 200 lbf (0.89 kN). A two-person haul team averages 375 lbf (1.67 kN) and a three-person haul team 500 lbf (2.22 kN). Though these forces are not seen with a free-moving load, these potentially higher forces need to be considered when looking at system safety.

Variables that affect the pulling power of a haul team include the type of surface under foot. Loose soil or a gravel surface will not permit as much traction as asphalt or concrete. The overall personality of the haul team also has an effect, such as when the team is tired and wet or overly energetic. Test results can be influenced by a haul team that has a competitive tug-of-war mentality. We have observed that physical size does not necessarily have a direct correlation to pulling power. Large hands do not always equate to high grip strength on a rope.

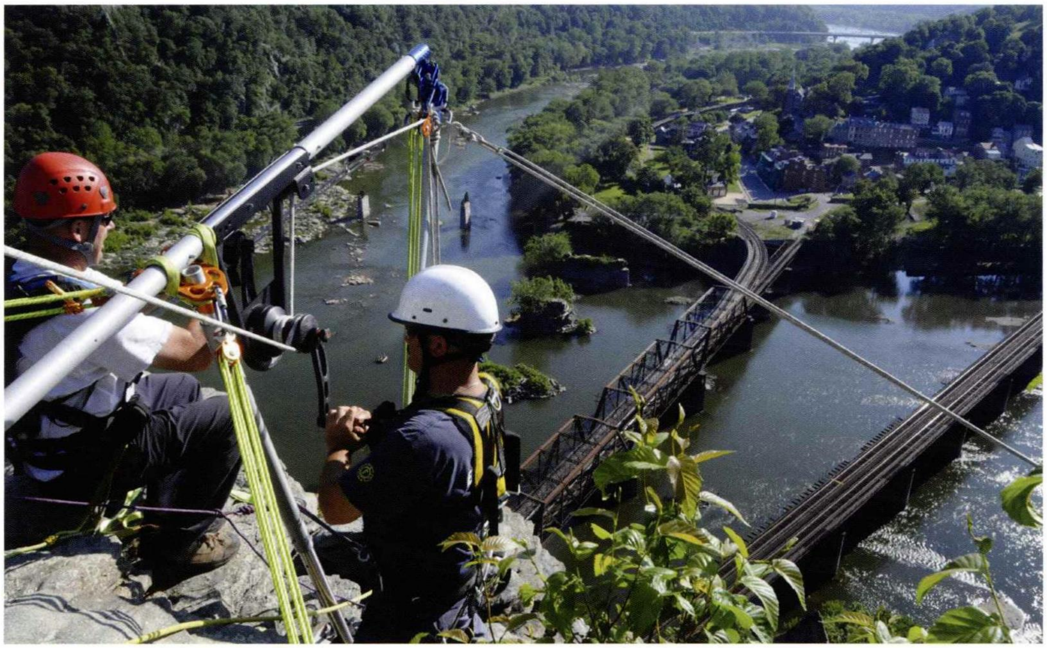
POWERED SYSTEMS

Whether human, electric, hydraulic or engine (PTO) powered, the advantage of a winch or a capstan is a reduction in the number of personnel required to lift the load. A winch has a cable attached to it and is most often found attached to a vehicle, although there are some gas-powered portable models around. A capstan uses the main line, relying on several wraps around the capstan to hold the rope. Unless the capstan is a self-tailing model, a rescuer is needed to maintain tension on the line to prevent it from slipping. Capstans can be hand cranked or powered, vehicle mounted or portable.

There are several disadvantages with the portable units, beginning with the bulk and weight, that may make it difficult to get them to the rescue scene. We have heard stories of temperamental power winches that could only be successfully operated by a particular team member. If they were not available, the winch could not be used. Another issue was the noise level, which made it difficult for the operator to hear commands. Vehicle-mounted units depend on access for the vehicle. You should never rely on any mechanical device to work. Always be ready to use a rope-based raising system.

Several rescue teams regularly use a cable winch mounted on the rescue truck for low angle and high angle evacuations. Be aware that the wire cable presents a significant hazard, should it break, and try to minimize the number of people that have to be in its vicinity. Protect the cable from sharp edges just as you do a rescue rope.

Some agencies prohibit the use of power systems as a general rule. To the best of our knowledge there has never been an accident as a result of using a cable winch or a capstan in an over-the-side rescue. Similar systems are also in regular use as hoists on helicopters. An advantage of the powered system is that a single operator can respond much more quickly than a multi-person haul team.



Capstan System

Cable Main Line with a Capstan for the Belay Line

SET-UP OF MECHANICAL ADVANTAGE SYSTEMS

1:1 System with Ratchet

Although a 1:1 system does not provide any mechanical advantage, it does eliminate the need to reset the system. If the load is light enough or if you have a large haul team, the 1:1 may be the most efficient system.

A variation of the 1:1 system is the counterbalance system. The change-of-direction pulley allows the haul team to walk downhill toward the litter using gravity to the team's advantage.

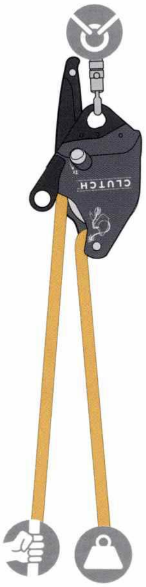


Figure 17-6a: 1:1 1 M/A System with the CLUTCH

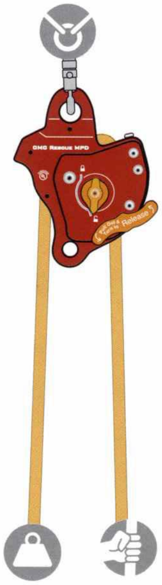


Figure 17-6b: 1:1 M/A System with the MPD

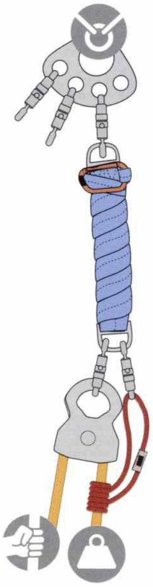


Figure 17-6c: 1:1 M/A System with a Ratchet

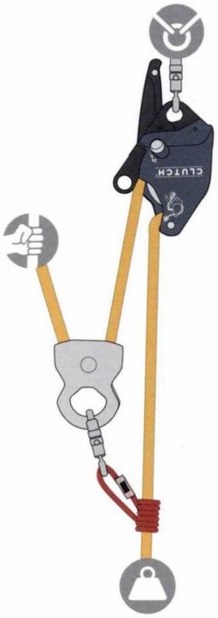


Figure 17-7a:
3:1 with CLUTCH

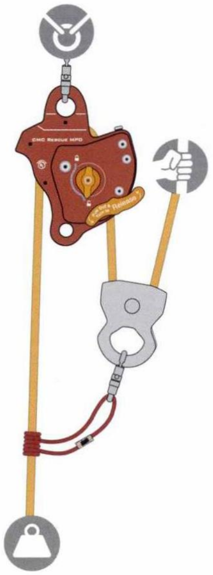


Figure 17-7b:
3:1 Using the MPD

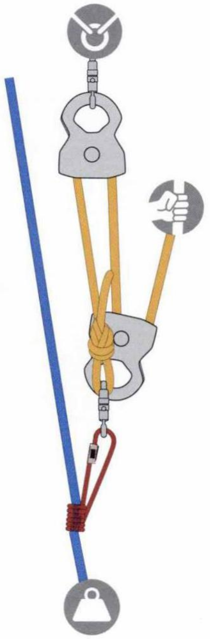


Figure 17-7c:
3:1 M/A Piggyback System

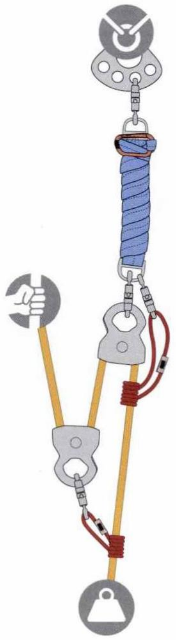


Figure 17-7d:
3:1 M/A System

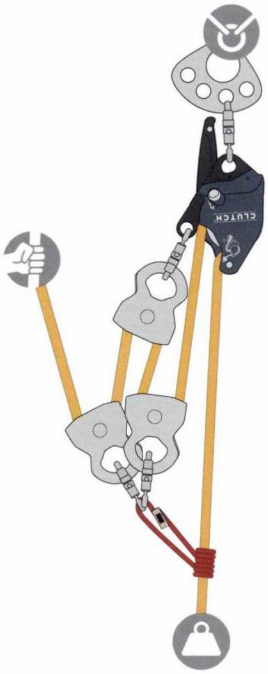


Figure 17-8: Simple 5:1 System

3:1 System

The classic Z-rig is probably the most commonly learned and used system. It can be set up using the main line or as a pre-rigged system and piggybacked onto the main line.

Simple 5:1 System

If a 3:1 system does not provide enough mechanical advantage during the raise, two pulleys can be added to change the system into a simple 5:1.

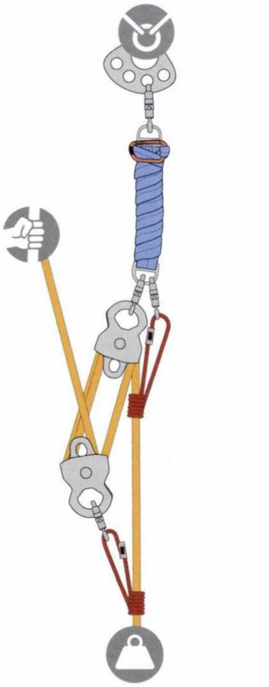


Figure 17-9a: Simple 5:1 System with Double Pulleys

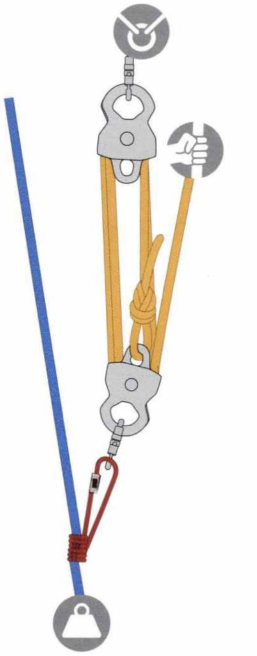


Figure 17-9b: Simple 5:1 Piggyback System with Double Pulleys

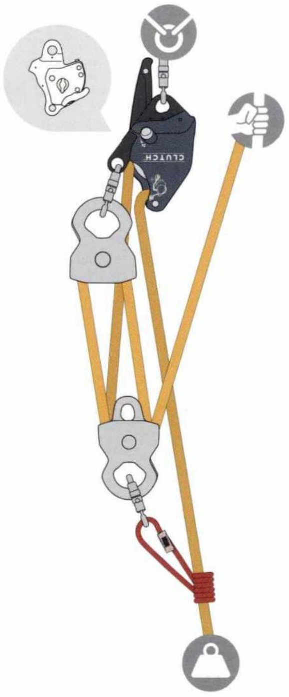


Figure 17-9c: Simple 5:1 System with Single and Double Pulley and the CLUTCH

5:1 M/A System with Double Pulleys

If it appears that the extra mechanical advantage of a 5:1 will be needed, double pulleys can be used. The system is rigged and operated much like a 3:1.

The bottom hole in the center plate of the double pulley is called a becket and is used to anchor one end of the rope rigged through the pulleys when the 5:1 is used as a piggyback system.

A 5:1 M/A system with small pulleys and 8 to 10 mm cord, such as the AZTEK system or AZTEK LT makes a compact mechanical advantage system that can be used to unweight a subject on a pick-off, lift the end of the litter on a mid-face patient scoop, or pass a knot on a raising or lowering system.

4:1 M/A System with Double Pulleys

The fire service ladder rig system is an inverted 5:1 with double pulleys and is the most common mechanical advantage system used for vertical lifts in confined space entry and rescue. Usually with a self-camming pulley, the system is suspended from a tripod. It is only a 4:1 (see Figure 17-10) since the top pulley acts as a change of direction, allowing the downward pull on the rope.

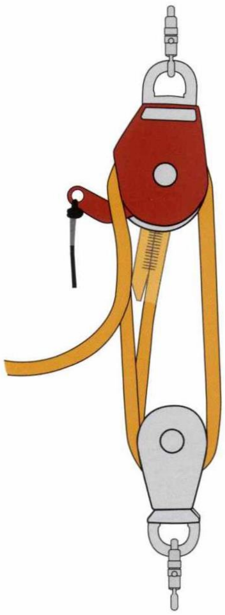


Figure 17-10: Simple 4:1 System with Double Pulleys

9:1 M/A System

If more mechanical advantage than 5:1 is needed, two spare pulleys can be used to set up a new 3:1 pulling on your original 3:1 system. This becomes a 9:1 compound system. The same system setup has now increased pulling power by three times without having to redo the original 3:1 system. An additional rope grab, preferably a Prusik hitch, will also be needed. Resetting the front 3:1 system automatically resets the rear 3:1.

Adding a Prusik hitch and moving the mechanical advantage pulley makes an easy conversion from a simple 5:1 to a compound 9:1 (see Figure 17-11).

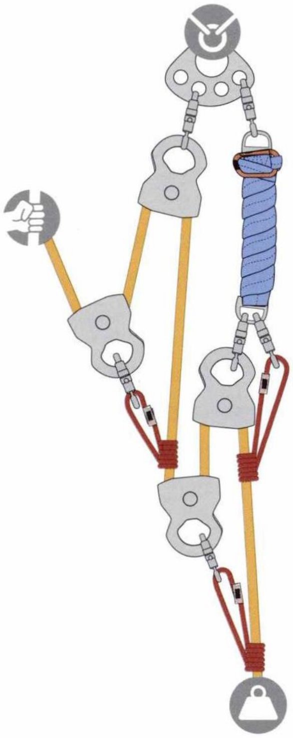


Figure 17-11a: 9:1 Compound M/A System

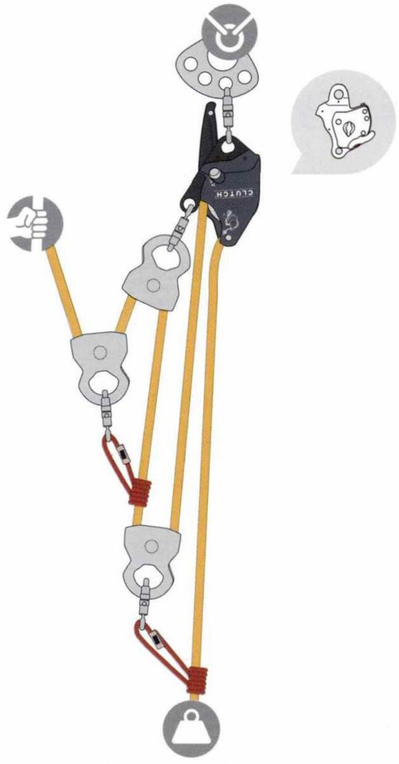


Figure 17-11b: 9:1 Compound M/A System with CLUTCH

5:1 Complex M/A System

This is an example of a complex system that also includes a change in the direction of the pull. Each pulley adds friction to the system. As a result, a complex system is more efficient than a simple system with a change of direction. How much more efficient depends on the quality of your pulleys. This can be significant if you do not have pulleys and have to use carabiners to rig the mechanical advantage system. The haul team pulls toward the load, which if the pull is downhill would give the haul team an advantage. One downside of a complex system is its need to reset more frequently since the pulleys are moving toward each other.

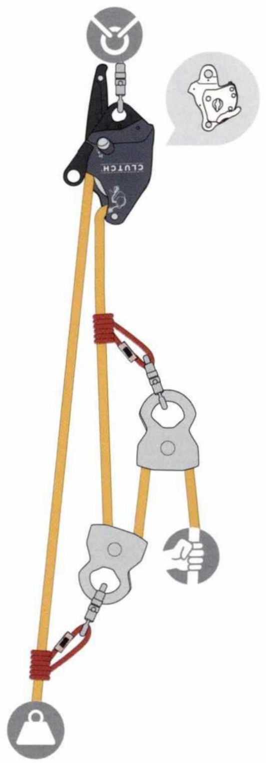


Figure 17-12a: 5:1 Complex M/A System with CLUTCH

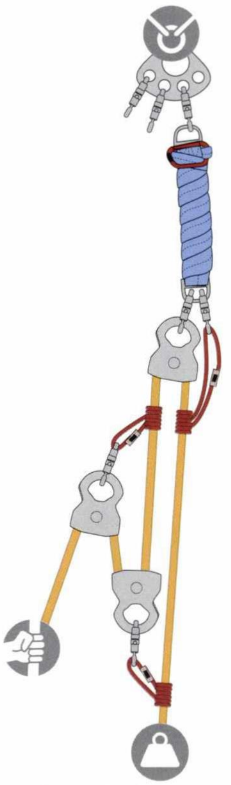


Figure 17-12b: 5:1 Complex M/A System

6:1 Compound M/A System

A 6:1 system is a compound system with a 3:1 pulled by a 2:1. A separate raising line is usually the easiest way to rig the 2:1 part of the system, or the end of the main line can be used. An extra rope grab and pulley are also needed. However, if you know how to set up a 3:1 and have the equipment, it is usually easier to rig a 9:1 than a 6:1.

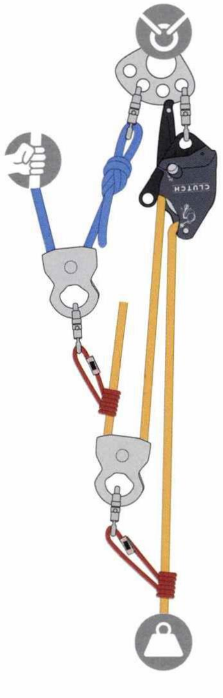


Figure 17-12c: 6:1 Compound M/A System with CLUTCH

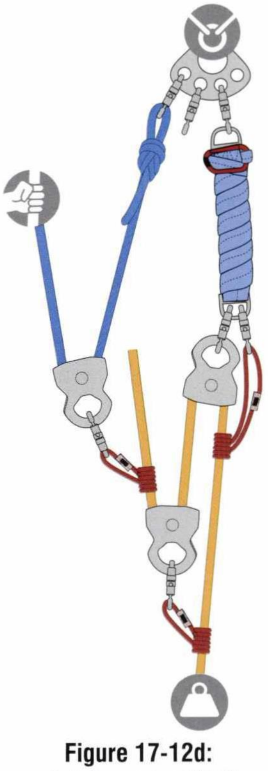


Figure 17-12d: 6:1 Compound M/A

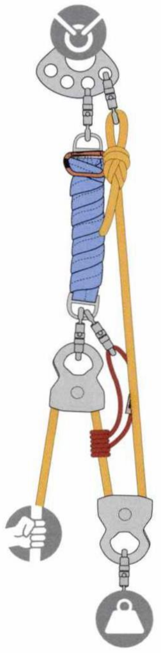


Figure 17-13a: 2:1 M/A System

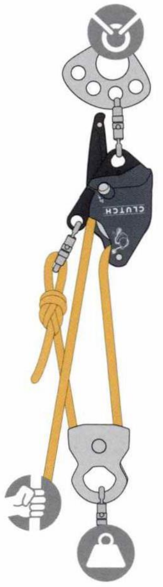


Figure 17-13b: 2:1 M/A System with MPD

2:1 M/A System

The 2:1 M/A system works well where only a small increase in pulling power is needed, such as for lifting a single person or where the litter is coming up at a low angle. Less rope is used within the system, so the M/A pulley is often connected directly to the load, which eliminates the need to reset the system. Adding a change-of-direction pulley allows the pull to be downward when used with a high anchor point, known as a *ladder rig* in the fire service.

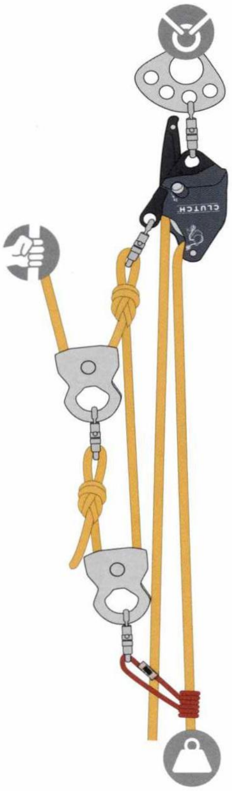


Figure 17-14: 4:1 Mechancial Advantage System

4:1 Compound M/A System

This 4:1 system has a higher mechanical advantage but uses the same number of pulleys and rope grabs as a 3:1 system. The 4:1 can be set up using two separate ropes or a single rope. It is usually rigged as a piggyback system.

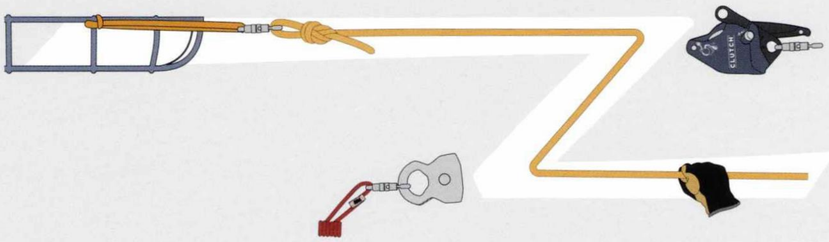
In order for the 4:1 system to pull the rope through the ratchet, the ratchet must be on the anchor side of the haul pulley. As discussed previously, the ratchet must be held in place for reasonable operating efficiency. The ratchet can be placed behind the system at the anchor if a rescuer is available to pull the rope through. A third pulley can make operating the Prusik used for the ratchet more efficient.

CMC PRO TIP

Good housekeeping is important when setting up systems to keep the ropes from tangling. Clip the hardware to yourself or the anchor when not in use.

CMC PRO TIP

When setting up the Z-rig (3:1), lay the rope out in the shape of a Z and then put a pulley at each of the bends.



Notes

PART
04
Rescue Systems

CHAPTER
18
Reversing a System

LEGEND: Anchor Grip Load

TERMINAL LEARNING OBJECTIVE

The student will demonstrate how to convert from a lowering to a raising system and from a raising system to a lowering system.

ENABLING LEARNING OBJECTIVES

1. Demonstrate the conversion of a lowering system to a raising system using a CLUTCH or MPD
2. Demonstrate the conversion of a lowering system to a raising system using a brake bar rack
3. Demonstrate how to convert a raising system to a lowering system using a CLUTCH or MPD
4. Demonstrate how to convert a raising system to a lowering system using a brake bar rack
5. Demonstrate how to construct and use a load release hitch or strap

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.2.16 | 5.2.18

Rescues often require the litter to be lowered to the patient and then brought back to the top. If the terrain permits, the quickest way to move the litter to the patient is to carry it down. On high angle terrain, it might be possible to lower the litter with a separate line. The early arrival of the litter allows the patient packaging to be done at the same time that the systems are being rigged.

If the litter must be supported by the rope systems while loading the patient, it probably will be best to use a lowering system to get to the patient and then a raising system for the evacuation. While the patient is being packaged, the systems can be converted from lowering to raising. This can be done while safely supporting the full weight of the patient, litter and tender.

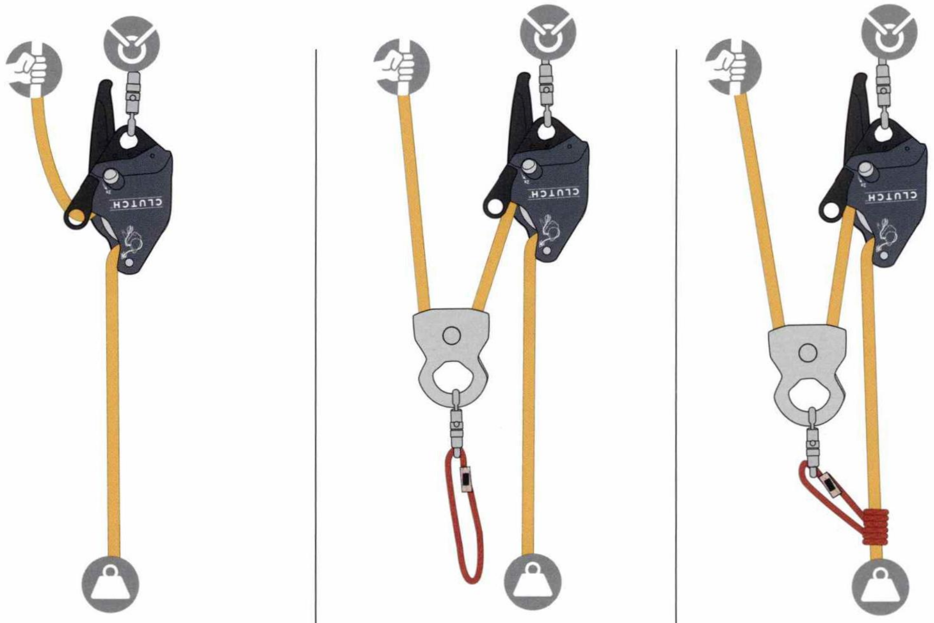
Even when the litter appears to be in a secure position, this procedure is recommended. It helps to be consistent, but more importantly, the litter may not be as secure as originally thought.

Sometimes the nature of the problem requires the litter to be raised to the patient and then lowered back down. Anchors will still have to be set above the patient, but the litter can start from below. While loading the patient, the systems are converted for lowering.

During any evacuation some problem may develop that can be resolved by briefly moving the litter in the opposite direction. This might be due to the difficulty of the terrain or a modification in the rescue plan brought on by a change in resources, such as the availability of a helicopter. The following procedures for reversing the direction of the systems allow such adjustments to be done quickly and safely.

A significant advantage of the Tandem Prusik belay is its ability to change system direction without doing anything at all; just pull the rope in the new direction. If a pulley is used with the raising belay, it should be removed when performing a lowering or added for a raising. The CLUTCH and the MPD have the same advantage; the only change is the direction that the rope moves.

Changing a Lowering System to a Raising System with the CLUTCH



Step 1

Rotate the CLUTCH Control Handle to Stop. Throughout the conversion the main line can continue to support the load. The belay line should be locked off or continually tended.

Step 2

Rig a pulley onto the running end of the rope and attach a carabiner.

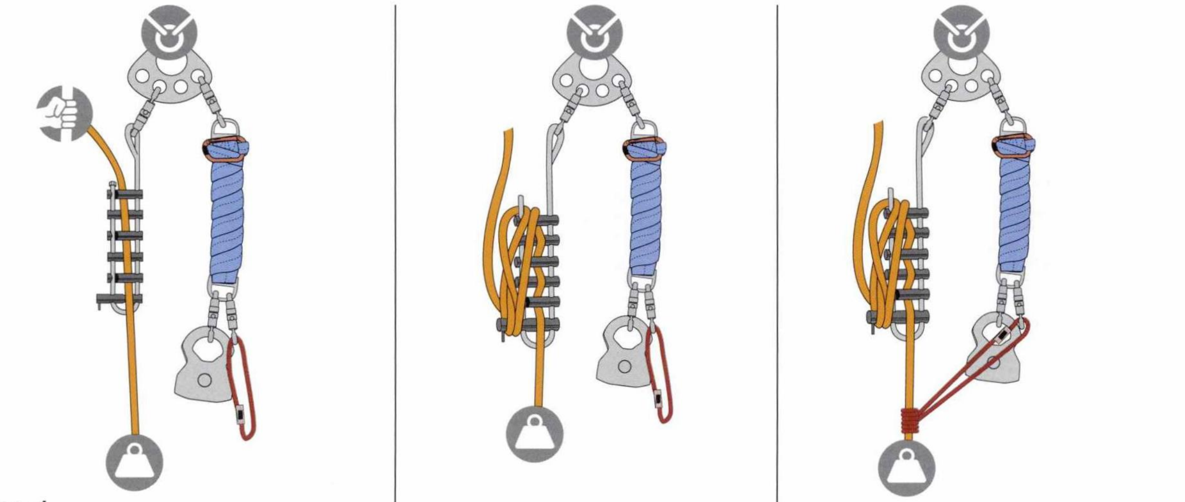
Step 3

Connect the pulley to the main line with a Prusik hitch. Rotate the CLUTCH Handle to Standby for highest effeciency. Your system is now a 3:1 M/A and you can tell the team leader you are ready to raise.

Figure 18-1: Lowering System to a Raising System with the CLUTCH

When the pulley reaches the anchor, the system will need to be reset. Release the tail end of the haul line and pull the prusik back towards the load. The auto-locking progress capture feature of the CLUTCH allows hands-free reset of mechanical advantage systems and easy stop/start of operations to communicate or resolve issues.

Changing a Lowering System to Raising System using a Brake Bar Rack



Step 1

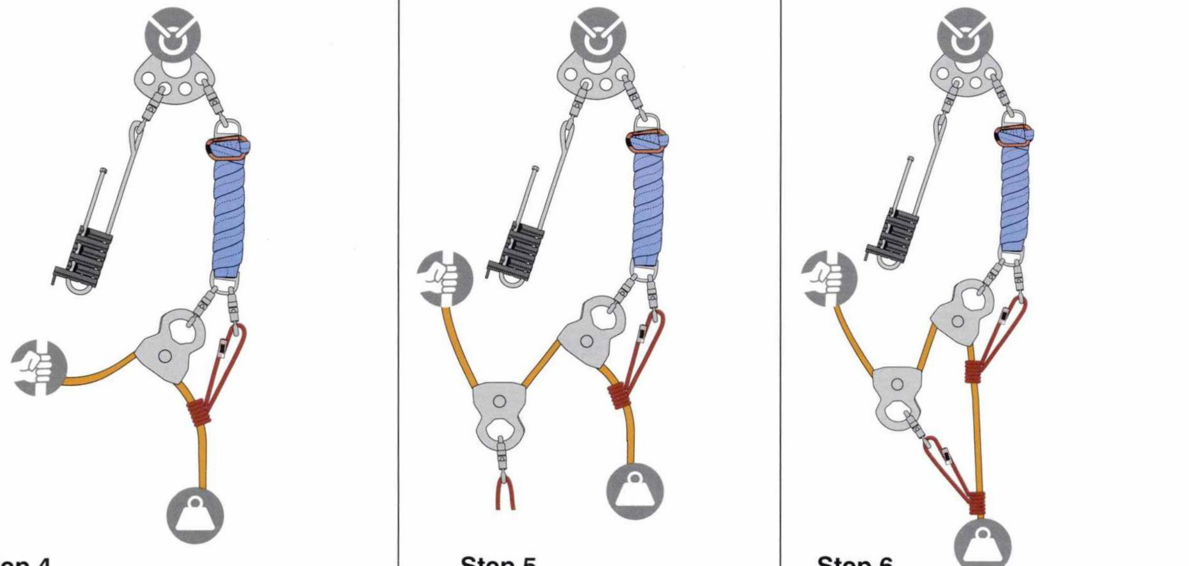
Throughout the conversion the load can remain supported by the main line. The belay line should be locked off or continually tended.

Step 2

Lock off the descender.

Step 3

Attach a rope grab for the ratchet on the main line.



Step 4

Unlock the descender and gently transfer the load onto the ratchet. Remove the rope from the descender and rig it through a pulley. Attach the pulley to the load release strap.

Step 5

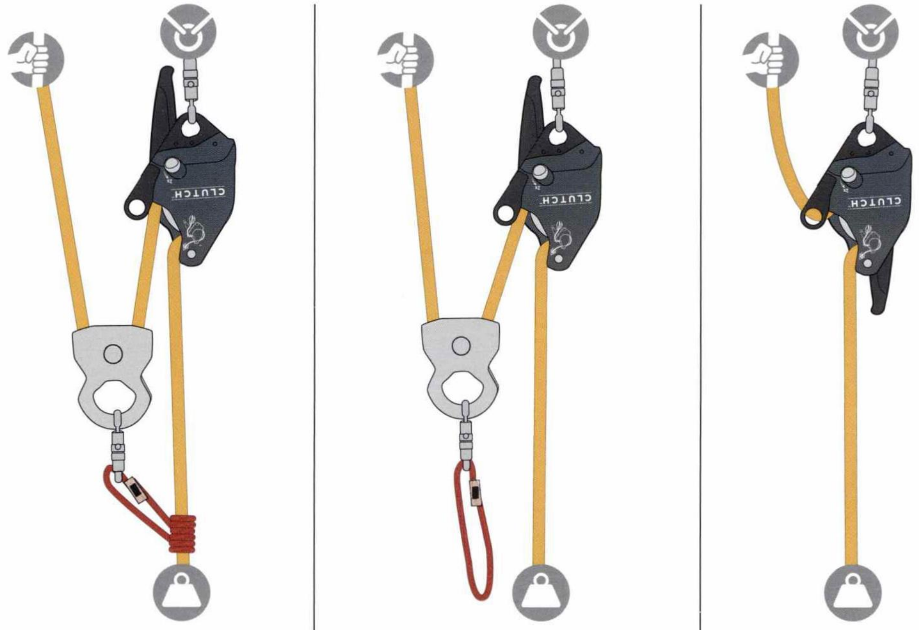
Rig a second pulley onto the running end of the rope and attach a carabiner.

Step 6

Tie a Prusik hitch onto the main line and clip it into the carabiner on the second pulley. Your system is now a 3:1 M/A and you can tell the team leader that you are ready to raise.

Figure 18-2: Lowering System to Raising System using a Brake Bar Rack

Changing a Raising System to a Lowering System using the CLUTCH



Step 1

Rotate the CLUTCH Control Handle to Stop. Throughout the conversion the main line can continue to support the load. The belay line should be locked off or continually tended.

Step 2

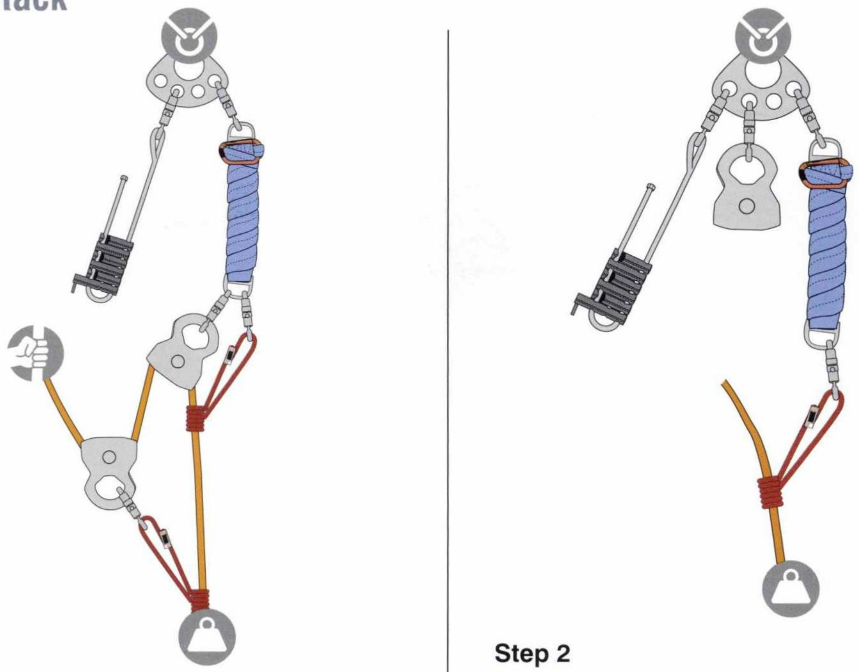
Remove the Prusik hitch and pulley.

Step 3

Rotate the CLUTCH Control Handle to Stand By and you can tell the team leader you are ready to lower.

Figure 18-3: Raising System to a Lowering System using the CLUTCH

Changing a Raising System to a Lowering System using a Brake Bar Rack

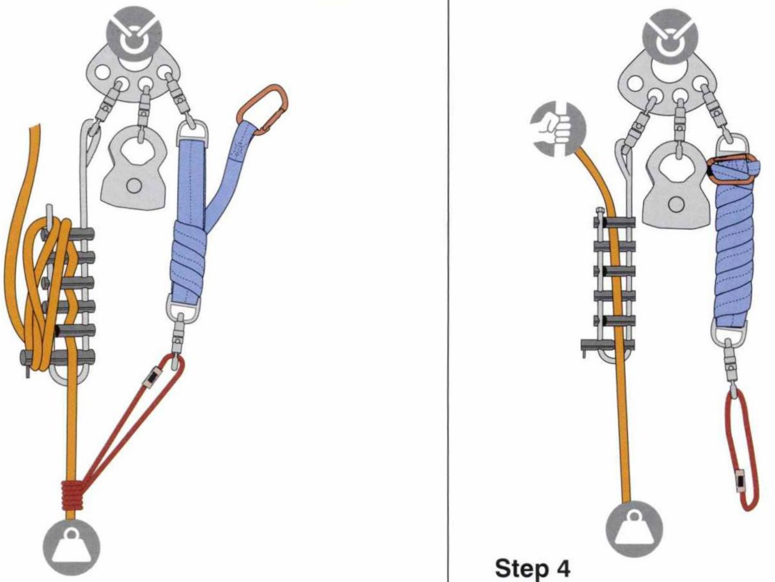


Step 1

Throughout the conversion the system load can remain on the main line. The belay line should be locked off or continually tended.

Step 2

Let rope out until the ratchet is holding the load. Remove the Prusik hitch and the pulleys and store them in a secure place.



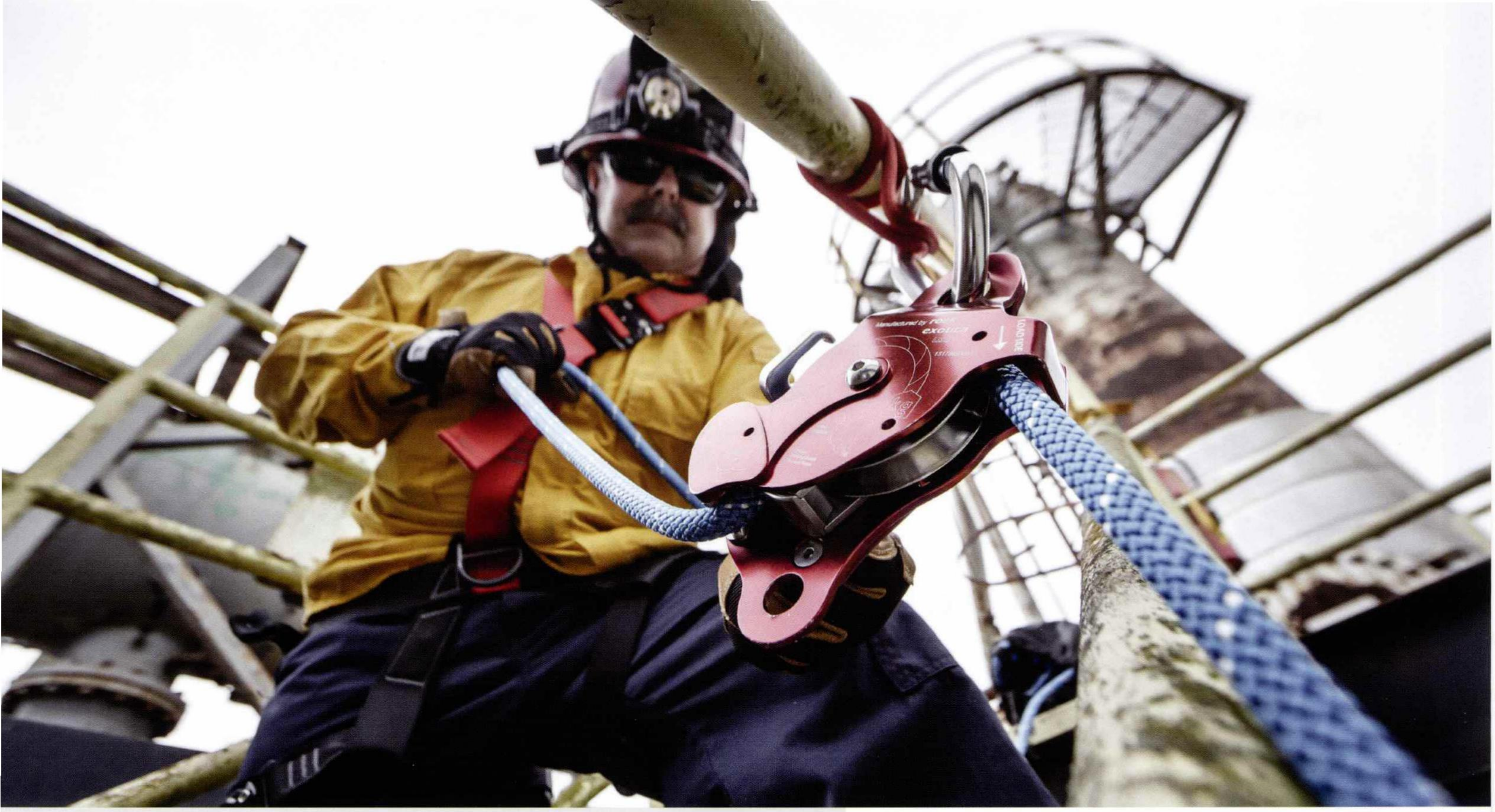
Step 3

Rig the rope onto the descender and lock it off. Try to eliminate the slack between the Prusik hitch and the rack. Carefully release the load release strap and transfer the load to the descender.

Step 4

Retie the load release strap. Your system is now a lowering system and you can tell the team leader that you are ready to lower.

Figure 18-4: Raising System to a Lowering System using a Brake Bar Rack



PART
04
Rescue Systems

CHAPTER
19
Knot Pass Through a System

LEGEND: Anchor Grip Load

TERMINAL LEARNING OBJECTIVE

The student will pass a knot through a lowering and raising system.

ENABLING LEARNING OBJECTIVES

1. Pass a knot through a descent control device
2. Pass a knot through a raising system
3. Pass a knot through a belay device during a raising and lowering operation

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.2.16 | 5.2.18

LOWERING SYSTEMS

Twin-Tension System

If the rescue allows the use of a Twin-Tension System, passing the knot is relatively simple as the system without the knot can be used to move the load (assuming you have staggered the knot locations). This puts the load entirely on one side of the Twin-Tension System, making it in effect temporarily a Main/Belay system. This system works well with the CLUTCH and MPD but can also be employed with other descent control devices used in a Twin-Tension System. We show two methods of passing a knot through a Twin-Tension Lowering System.

Twin-Tension Knot Pass with a Figure 8 Loop

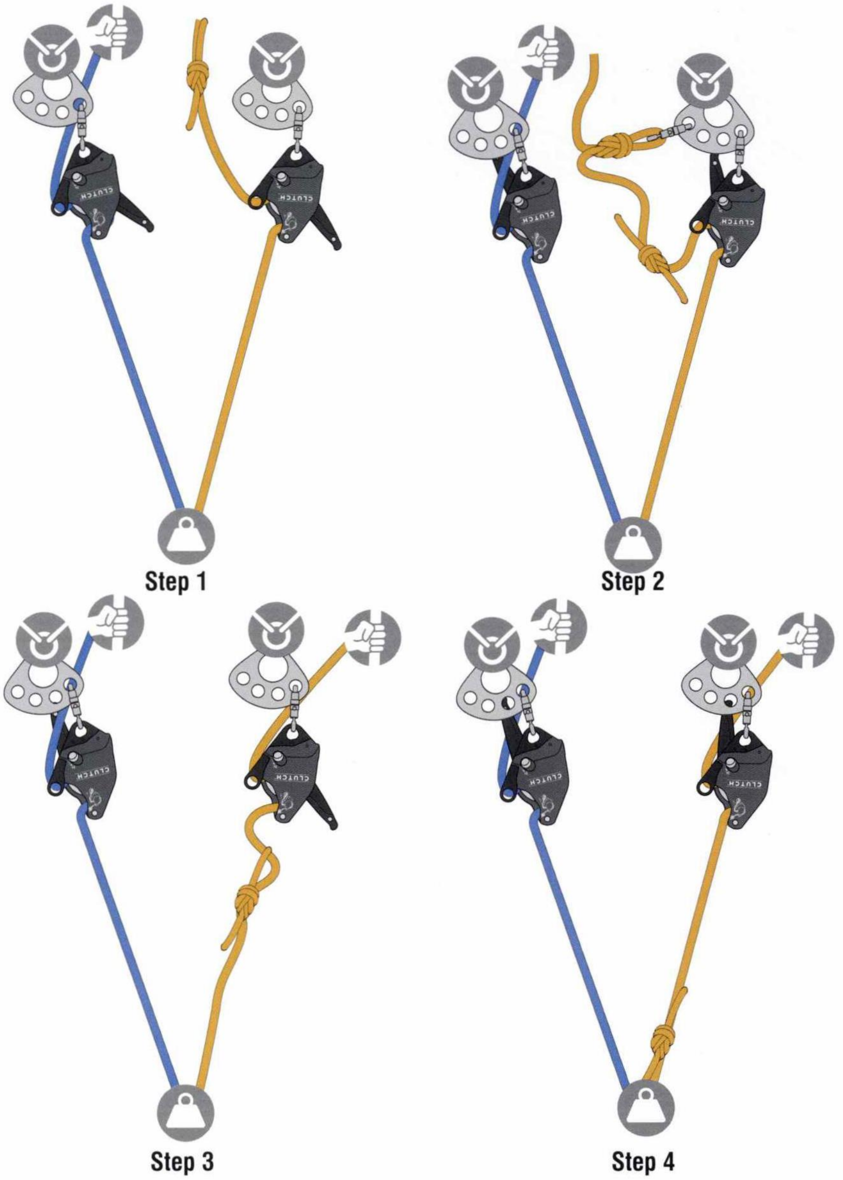


Figure 19-1: Twin-Tension Knot Pass with a Figure 8 Loop

Step 1

Stop lowering when the knot is about 18 in (0.5 m) above the CLUTCH.

Step 2

About 3 ft. (1 m) above the knot, tie a figure 8 loop and attach it to the anchor.

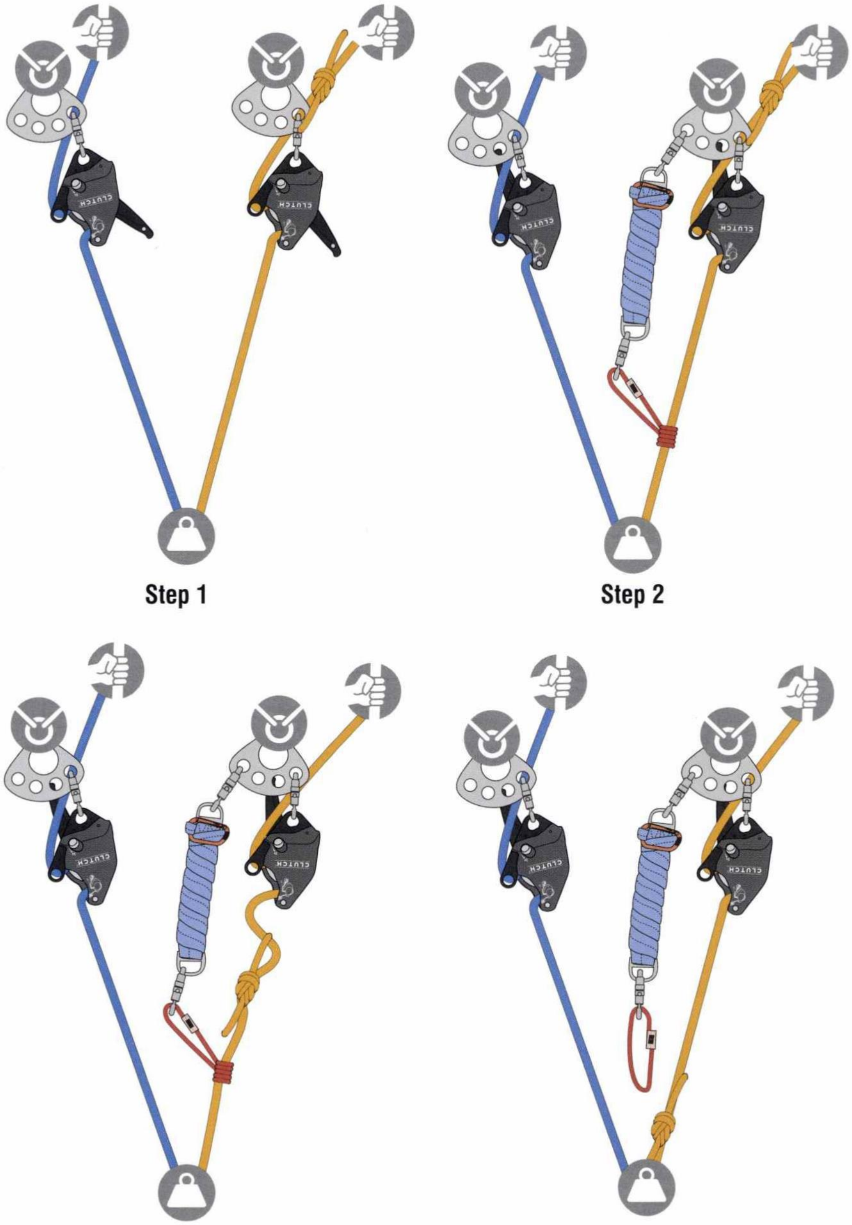
Step 3

Continue to lower until the entire load rests on the second rope system. Remove the rope from the CLUTCH and rig the rope with the knot below the CLUTCH.

Step 4

Disconnect the figure 8 loop from the anchor and untie it. Continue the lowering allowing the tension on both ropes to equalize again.

Twin-Tension Knot Pass with a Prusik Hitch



Step 1

Step 2

Step 3

Step 4

Figure 19-2: Twin-Tension Knot Pass with a Prusik Hitch

Step 1

Stop lowering when the knot is about 18 in (0.5 m) above the CLUTCH.

Step 2

Attach a Prusik hitch to the anchor using a load release strap or knot.

Step 3

Continue to lower until the entire load rests on the second rope system. Remove the rope from the CLUTCH and rig the rope with the knot below the CLUTCH.

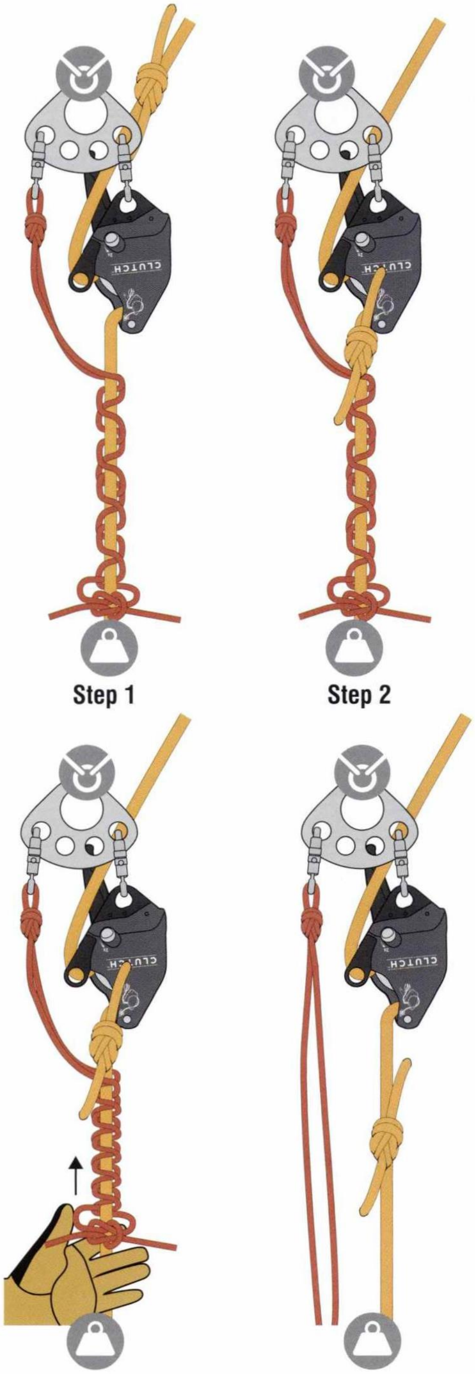
Step 4

Disconnect the Prusik hitch from the rope and the load release from the anchor. Continue the lowering allowing the tension on both ropes to equalize again.

Note: This method also works with the MPD.

Dog and Tails Method

The easiest and least equipment intensive method of passing a knot is with the Dog & Tails. A 15 ft. (4.6m) length of 8 mm cord is all you need. The Dog & Tails method works with a CLUTCH, MPD, Brake Bar Rack and other descent control devices.



Step 1 Step 2

Step 3 Step 4

Figure 19-3: Knot Pass with Dog and Tails

Step 1

Stop lowering when the knot is about 18 in. (0.5m) above the CLUTCH. Tie a Figure 8 on a Bight at the center of the 8mm cord and connect it to the anchor. Starting just in front of the CLUTCH, crisscross the two lengths of the cord around the rope at least 10 times, counting the crosses over the top. Finish with a square knot, then tighten by milking towards the load.

Step 2

Lower with the CLUTCH to transfer the tension to the Dog & Tails. Remove the rope and rig it with the knot below the CLUTCH. Rotate the CLUTCH handle to Stop (since there is no tension on the rope at the CLUTCH at this moment.)

Step 3

Grip the Dog & Tails at the end toward the load and slowly work it back towards the anchor which will transfer the load back onto the CLUTCH.

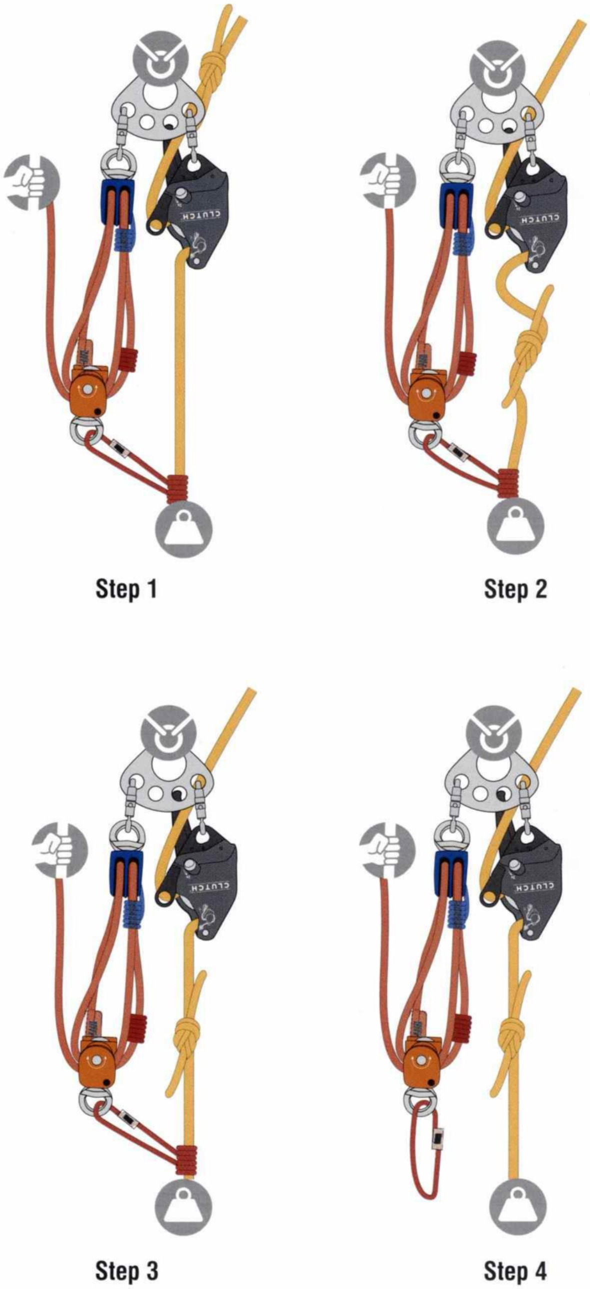
Step 4

Remove the cord, rotate the CLUTCH handle to Stand By and tell the team leader you are ready to lower.

Note: This method also works with the MPD.

Mechanical Advantage Piggyback Method

This method requires a separate M/A system such as an AZTEK or other self-contained haul system. Some teams include sufficient gear for a raising or a lowering in each rope kit, so the pulleys from the belay kit could be used and the end of the Main line above the CLUTCH for the rope. The advantage to the M/A Piggyback is that it also works for passing a knot when raising. This method works with a CLUTCH, MPD, Brake Bar Rack and other descent control devices.



Step 1 **Step 2**

Step 3 **Step 4**

Figure 19-4: Knot Pass with a Mechanical Advantage

Step 1

Lower until the knot is just above the CLUTCH and rotate the CLUTCH handle to Stop. (Stop about 18 in. (0.5m) above a Brake Bar Rack so you have enough rope to tie off the Rack.) Connect the piggyback system to the anchor, and then using a Prusik hitch, attach it to the rope.

Step 2

Lower using the CLUTCH to transfer the tension to the piggyback system. Remove the rope from the CLUTCH and rig with the knot below the CLUTCH. Rotate the CLUTCH handle to Stop, as at this point there is no tension on the rope entering the CLUTCH.

Step 3

Using the mechanical advantage of the piggyback system, lower until the tensions is back on the CLUTCH.

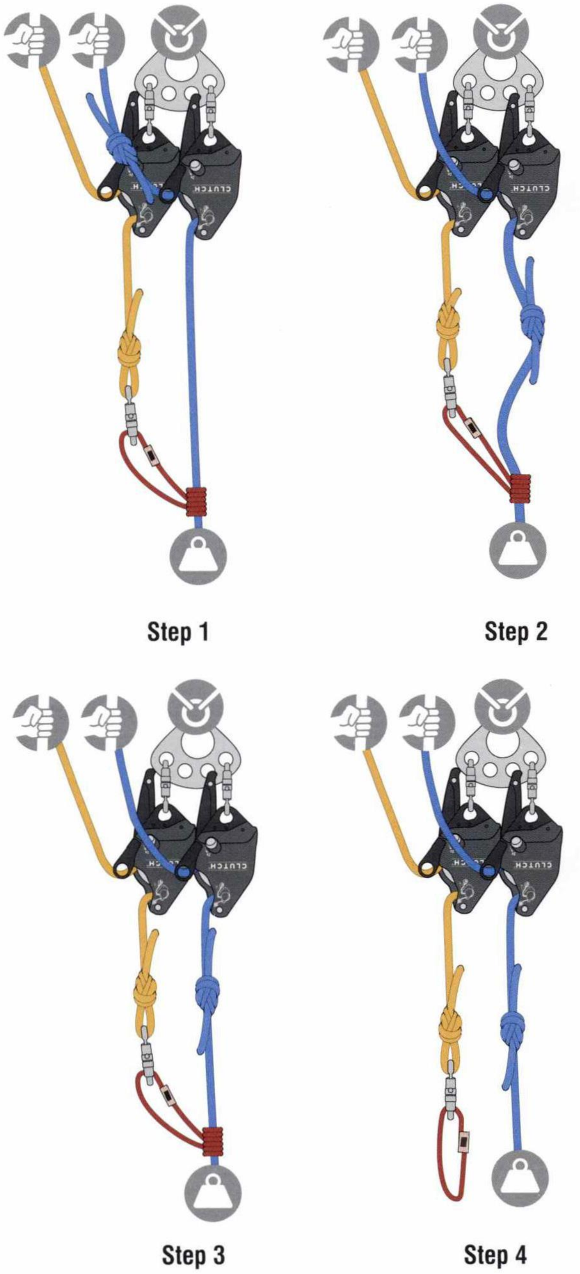
Step 4

Pull a little slack through the piggyback system and remove it from the rope. Continue to lower.

Note: This method also works with the MPD.

Lowering Piggyback Method

This method requires a second descent control device and rope, but as mentioned above, if both sides of a Main/Belay system have complete kits, then a second device would be available along with the tail of the main line. Again, this method works with a CLUTCH, MPD, Brake Bar Rack and other descent control devices.



Step 1

Step 2

Step 3

Step 4

Figure 19-5: Knot Pass with a Piggyback

Step 1

Lower until the knot is just above the CLUTCH and rotate the CLUTCH handle to Stop. (Stop about 18 in. (0.5m) above a Brake Bar Rack so you have enough rope to tie off the Rack.) Attach the piggyback system to the anchor using a Prusik hitch to the main line. Remove as much slack as possible.

Step 2

Release the main line CLUTCH and transfer the tension to the piggyback system. Then move the knot below the main line CLUTCH and rotate the CLUTCH handle to Stop.

Step 3

Using the piggyback lowering system, transfer the tension back to the main line CLUTCH.

Step 4

Pull some rope through the piggyback system and remove it from the main line. Continue to lower.

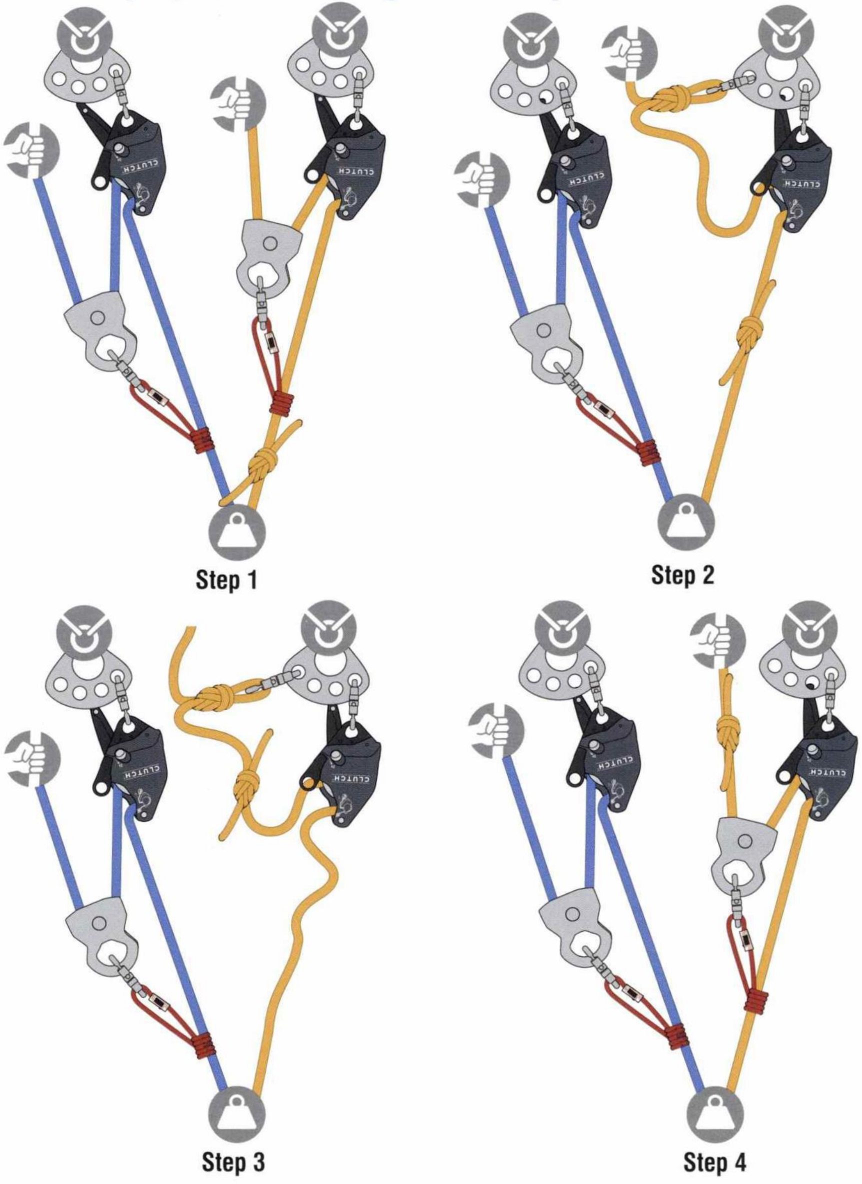
Note: This method also works with the MPD.

RAISING SYSTEMS

Twin-Tension System

Same as with the Lowering Knot Pass, if the rescue allows the use of a Twin-Tension System, passing the knot is relatively simple as the system without the knot can be used to move the load (assuming you have staggered the knot locations). This puts the load entirely on one side of the Twin-Tension System, making it in effect a temporary Main/Belay system. This system works well with the CLUTCH and MPD but can also be employed with other descent control devices used in a Twin-Tension System. We show two methods of passing a knot through a Twin-Tension Lowering System.

Raising System with Figure 8 Loop



Step 1

Step 2

Step 3

Step 4

Figure 19-6: Twin-Tension Knot Pass with a Figure 8 Loop

Step 1

Raise until the Prusik hitch and the knot is about 5 ft. (1.5 m) below the CLUTCH. Reset the Prusik hitch on the other rope.

Step 2

Pull slack from the 3 to 1 system and tie a figure 8 loop in the rope. Connect to the anchor.

Step 3

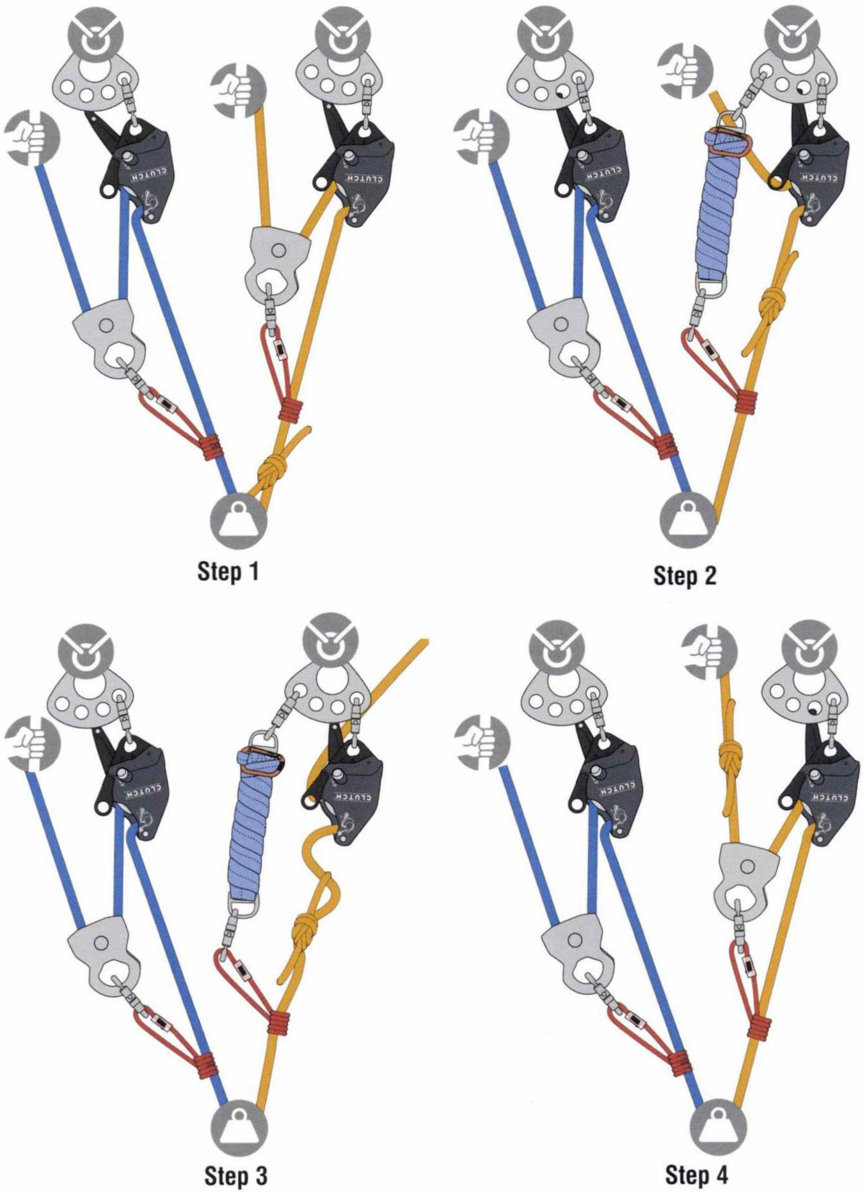
Continue to haul on the second rope until sufficient slack is created in the first rope. Remove the rope from the CLUTCH and then rig with the knot above the CLUTCH. Disconnect the figure 8 loop and untie it.

Step 4

Remove the Prusik hitch and then rig the 3 to 1 system below the CLUTCH. Continue the raise.

Note: This method also works with the MPD.

Raising System with a Prusik Hitch


Step 1

Step 2

Step 3

Step 4

Figure 19-7: Twin-Tension Knot Pass with a Prusik Hitch

Step 1

Raise until the Prusik hitch and the knot is about 5 ft. (1.5 m) below the CLUTCH. Reset the Prusik hitch on the other rope.

Step 2

Disconnect the haul Prusik hitch and pulley. Attach a Prusik hitch to the rope below the knot. Connect the Prusik hitch to the anchor with a load-release strap or hitch.

Step 3

Continue to haul on the second rope until sufficient slack is created in the first rope. Remove the rope from the CLUTCH and then rig with the knot above the CLUTCH.

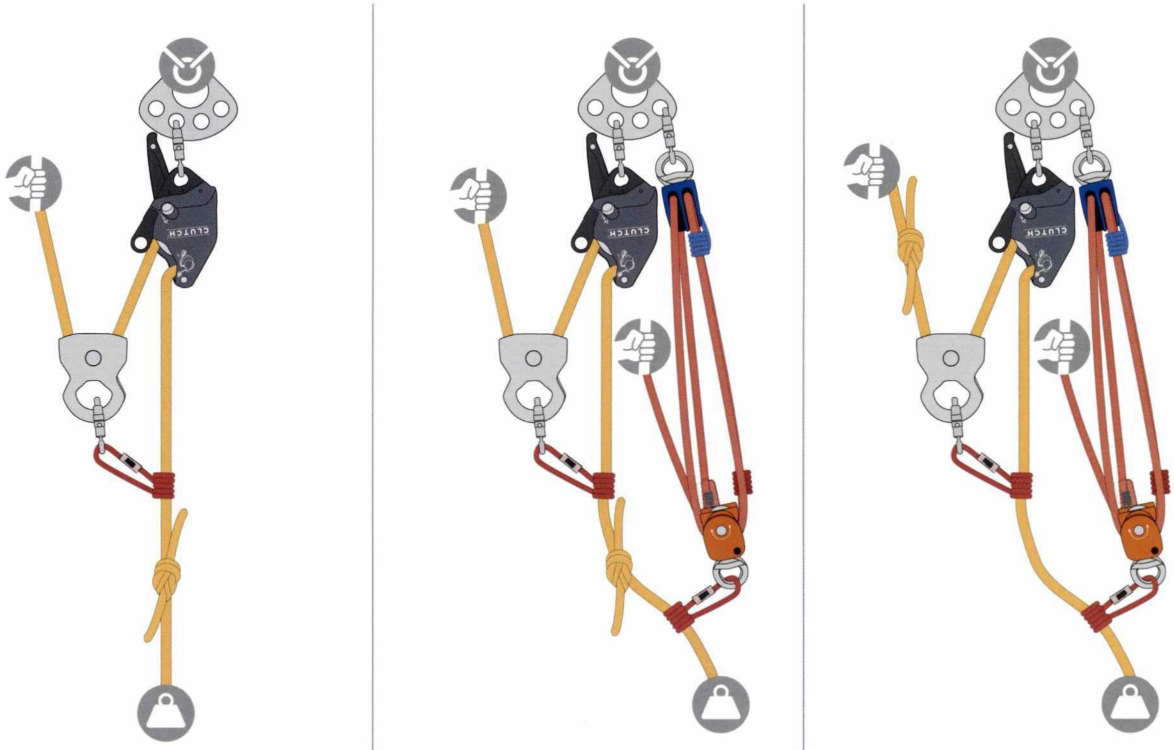
Step 4

Remove the Prusik hitch and load-release. Then rig the 3 to 1 system and continue the raise.

Note: This method also works with the MPD.

Mechanical Advantage Piggyback Method

This method requires a separate M/A system such as an AZTEK or other self-contained haul system. Some teams include sufficient gear for a raising or a lowering in each rope kit, so the pulleys from the belay kit could be used and the end of the Main line about the CLUTCH for the rope. This method works with a CLUTCH, MPD, Brake Bar Rack and other descent control devices.



Step 1

Raise until the knot is just below the CLUTCH and rotate the CLUTCH handle to Stop. (Stop about 18 in. (0.5m) above a Brake Bar Rack so you have enough rope to tie off the Rack.) Connect the piggyback system to the anchor and then using a Prusik hitch, attach it to the rope.

Step 2

Raise with the piggyback system until the knot can be moved to the other side of the CLUTCH. Space must be allowed to between the piggyback system and the knot to install the CLUTCH. Remove the rope from the CLUTCH and rig with the knot past the CLUTCH. Remove any slack and rotate the CLUTCH handle to Stop.

Step 3

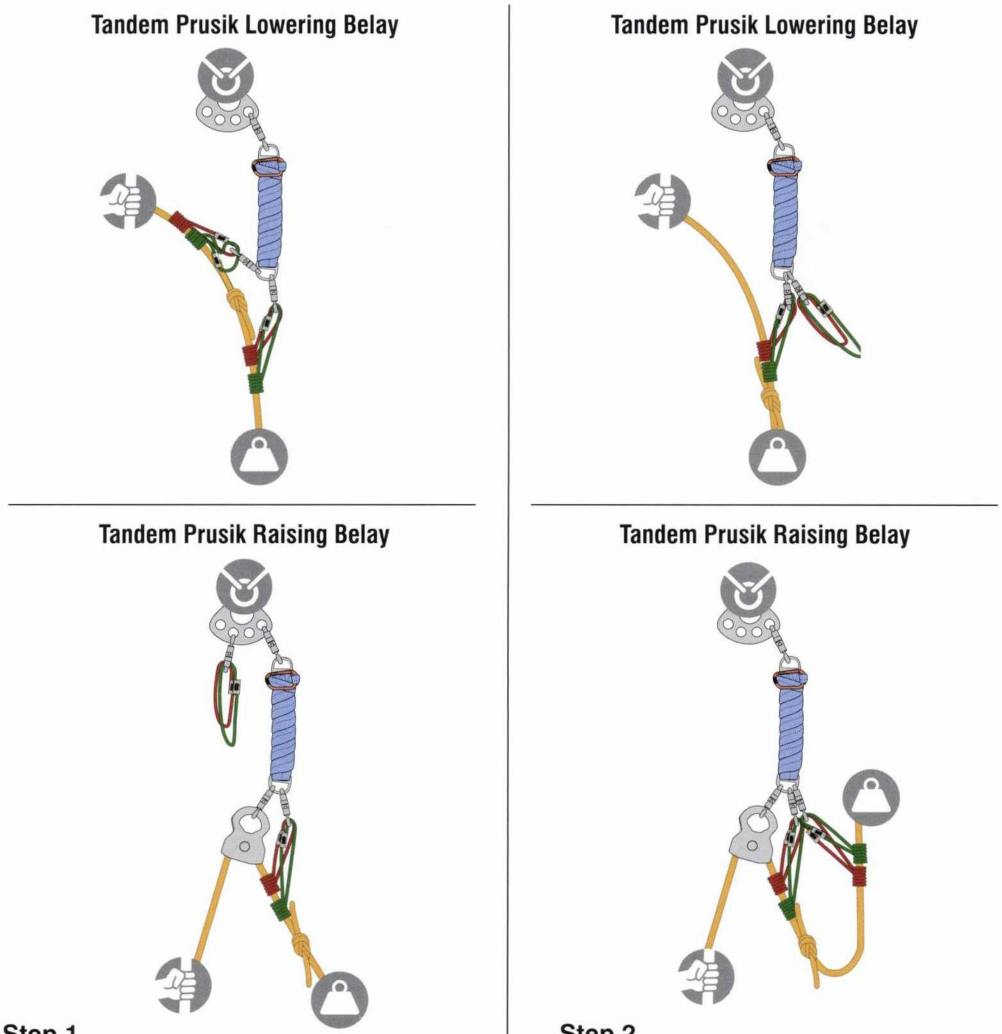
Using the piggyback system, lower until the load is again on the CLUTCH. Remove the piggyback system and continue to raise.

Note: This method also works with the MPD.

Figure 19-8: Mechanical Advantage with a Piggyback

Tandem Prusik Belay

This works for both a raising and a lowering system. For the pulley in the raising belay, pull rope through the system as the raising continues. When you have enough slack, remove the pulley and rig it below the knot.


Tandem Prusik Lowering Belay

Tandem Prusik Lowering Belay

Tandem Prusik Raising Belay

Tandem Prusik Raising Belay

Step 1

To pass a knot through a Tandem Prusik belay while maintaining belay protection, you will need a second pair of Prusik loops. As the knot approaches the Prusik hitches, use the second pair of Prusik loops to tie a Tandem Prusik belay on the other side of the knot. Connect them to the Load Release Strap with a second carabiner.

Step 2

Next, remove the first Tandem Prusik belay. With a raising, leave enough space between the knot and the new hitches to move the pulley past the knot. The knot is now through the belay and you can continue with the raising or lowering.

Figure 19-9: Tandem Prusik Lowering and Raising Belay

PART
04
Rescue Systems

CHAPTER
20
Analyzing a Rope Rescue System

LEGEND: Anchor Grip Load

TERMINAL LEARNING OBJECTIVE

The student will describe how forces are generated in a rescue system and how to analyze the system to determine the safety factors.

ENABLING LEARNING OBJECTIVES

1. Explain the "whistle test"
2. Explain the "T" method of calculating mechanical advantage
3. Identify the critical points of force in a mechanical advantage system
4. Explain the difference between actual and theoretical mechanical advantage

A rope rescue system is a group of components linked together to move the load. A system analysis is looking for where and at what force a system can fail, the weak link in the chain. System failure can happen in many ways and each type of failure can have a different consequence. When a component fails and the load is released, it is a catastrophic failure. When a component fails and the load is not released, but the system quits working, while not catastrophic in the classic sense, it can have catastrophic consequences for the patient in the litter if it takes a long time to fix the problem. Sometimes these non-catastrophic failures can be quickly repaired and if the reason for the system overload can be resolved, the rescue can be completed quickly and successfully.

When analyzing a rope rescue system, it is important to remember we are looking at the complete system, not just the individual components. Each component has a MBS that is determined by a specific test method. Sometimes these test methods do not reflect how a component is used in a system. Understanding these differences and how they affect the strength of the component is important to understanding the MBS of the system. For example, rigging through a descender or tying a knot will reduce the tensile strength of the rope. A piece of one-inch webbing is also tested without knots or bends, but many times it is rigged as an anchor that includes multiple wraps of webbing, making it stronger than the MBS determined by the test method. Change-of-direction pulleys can act as force multipliers, placing up to twice the weight of the load on the pulley and anchor. These are just some of the factors that must be considered in a system analysis.

ROPE RESCUE SYSTEM ANALYSIS

The analysis of a rope system consists of three parts: the ***critical point analysis***, the ***whistle test*** and the ***white board analysis***. Do a thorough analysis when you are selecting your organization's standard rope rescue systems. Because the size of the load and the load-bearing capacity of the anchors are often unknown, a quick analysis should also be done on scene.

A complete system analysis looks at both static and dynamic loads as system failures most often occur during dynamic loading. All of the different variables of a system under a dynamic load need to be considered. The shock-absorbing effect of rope elongation is one example as different ropes have different elongation characteristics. The amount of rope in the system affects how much elongation is available to absorb energy. These are just a couple of examples of things to look at to determine if you have an adequate Dynamic System Safety Factor (DSSF). Analyzing a static system does not look at all of the dynamic variables when determining the Static System Safety Factor (SSSF), so a higher margin of safety is required. This simplified SSSF analysis is the field expedient process used before putting people at risk.

Critical Point Analysis

The critical point analysis looks at each component and asks whether a failure of that component would cause a catastrophic failure of the system. If a critical point is found, it should be eliminated by a redundant component or backed up in some way. Remember to include the belay in the analysis as it provides the backup for most of the main line components. Sometimes the potential for failure of a critical point is low or the addition of redundant components actually increases the overall hazards, so the critical point is allowed to exist in the system. An example would be the single rope technique used in cave rescue.

Whistle Test

The whistle test determines what the system will do if all the operators let go at the same time. A swarm of hornets or a bolt of lightning could distract both the haul team and the belayer at the same time. If everyone lets go at once, the load should not fall. The Tandem Prusik belay is an example of a system that passes the whistle test. A Munter hitch is an example of a belay system that would not pass the whistle test. Due to the potential consequences of an actual system failing to pass the whistle test, it is best left as a theoretical analysis.

White Board Analysis

The white board analysis determines the force on each component based on the way it is used in the system. A rescue system is a chain built from many individual pieces of equipment. The way each link is rigged affects its individual strength, which determines the overall system strength. As discussed below, the system safety factor is a function of the weakest link in the system. The white board analysis should evaluate both static loads and dynamic loads.

A white board analysis entails drawing out the system on the board, including any angles, change-of-direction pulleys or other factors that would affect the forces on the system. A simple static system will be used as the first example. Because the forces in kN provide smaller numbers, the relationships are easier to picture. While the numbers used in the example are approximate, your team's analysis should use the actual strength of each component.

While all systems start with an anchor, the anchor point itself is one of those factors you might not be able to include in the analysis ahead of time because it is usually different at each rescue location. However, some teams do have anchors that are used repeatedly, such as the tie-off points on the rescue truck. These fixed types of anchors can be included in the analysis. The equipment used to build an anchor system can also be considered beforehand.

Our example starts with a single loop of one-inch webbing tied with a water knot around a BFR. By keeping the interior angle at 90°, we know the anchor strength should be about 21 kN (4,720 lbf). Since we have selected a BFR for the anchor point, we know its strength far exceeds the load.

The aluminum carabiners connecting the rope to the anchor and to the load are rated at 30 kN (6,744 lbf). These carabiners meet the requirements of NFPA 1983 for technical use. The 12.5 mm ($^1/_2$ in) rope is rated at 40 kN (8,992 lbf). This rope meets the requirements of NFPA 1983 for general use. Strength loss in the rope will vary with different knots, but in this example we will use 25%, which reduces the rope strength at the knot to 30 kN (6,744 lbf).

The system load is another factor that cannot be known ahead of time, but a close enough estimate can be made. For this example, we will use 200 kg (440 lb), a standard load used for rescue tests. A 200 kg (440 lb) load exerts a force of 2 kN (450 lbf) on the system. Because there are no pulleys or other angles that affect the forces in this simple system, the 2 kN (450 lbf) force is exerted on each of the system components.

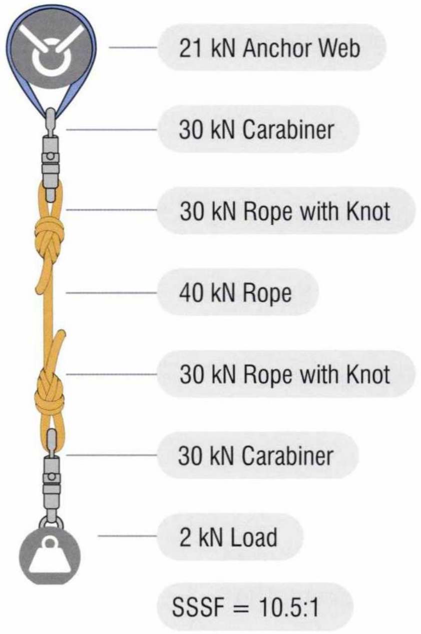


Figure 20-1: Simple System, First Example

Looking at the system we can determine which component is the weakest link, in this case the single webbing loop used to tie the anchor. By dividing the strength of the weakest link, 21 kN (4,720 lbf), by the 2 kN (450 lbf) force, we get a SSSF of 10.5:1 (see Figure 20-1).

To increase the SSSF make the weakest link stronger. By wrapping the webbing around the anchor twice, so the load is now supported by a double loop of webbing, the strength of the anchor web increases to 38 kN (8,542 lbf). Going to the redundant wrap 2, pull 1 adds redundancy and even more strength, 43 kN (9,667 lbf). This now makes the anchor web the strongest link in the system. The new weak links are the carabiners and the rope. With the knot at 30 kN (6,744 lbf), the SSSF has increased to 15:1 (see Figure 20-2).

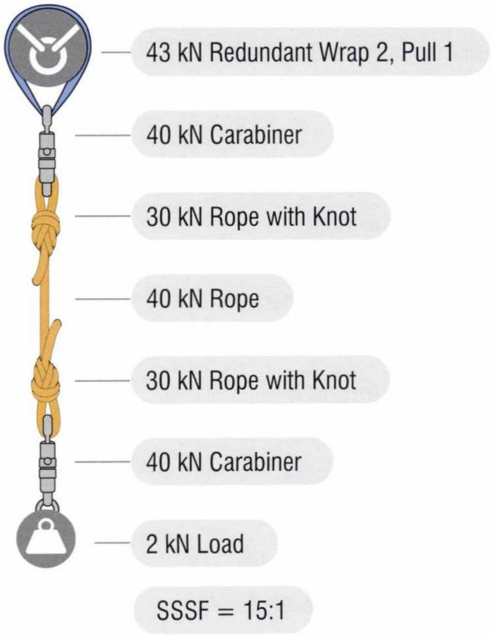


Figure 20-2: Simple System, Second Example

With this knowledge a rescue team could implement a SOP that requires a doubled loop when tying anchors with one-inch webbing. If the SOP includes a maximum 90° interior angle for the loop, the anchor web will never be the weakest link in the system. Safety in the field has been increased by doing the analysis before putting anyone at risk.

Replacing the 30 kN (6,744 lbf) technical-use carabiners with general-use carabiners rated at 40 kN (8,992 lbf) to match the NFPA rating of the rope, which many people feel would make the system safer, does not increase the SSSF. System-based analysis, compared to component-based analysis, requires the complete system to be evaluated again to look for the weak link. In this case, the weak link remains at 30 kN (6,744 lbf), which is the strength of the rope with the knot.

Figure 20-3 shows a system that might actually be used in a rescue. The knot at the top of the system has been replaced by a fixed pulley rated at 36 kN (8,093 lbf), which meets the requirements of NFPA 1983 for general use. The pulley acts as a force multiplier. If the force on the system is 2 kN (450 lbf), the force on the pulley, carabiner and anchor will be 4 kN (900 lbf). Remember that a fixed pulley that has a 0° interior angle doubles the load at that point. If at 30 kN (6,744 lbf), the carabiner is the weak link, then dividing by the 4 kN (900 lbf) force results in a

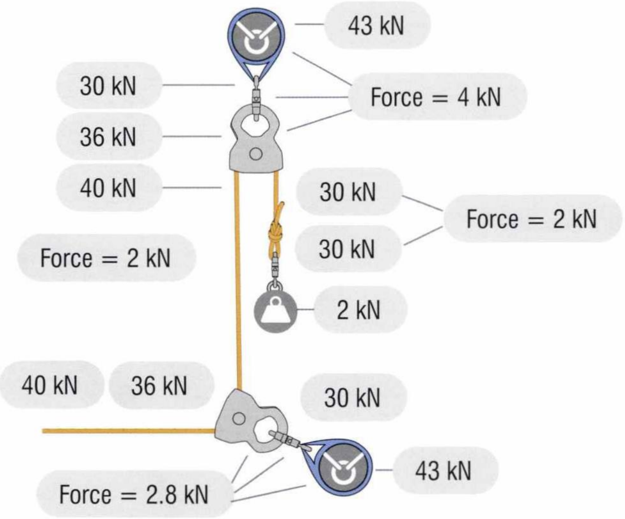

43 kN
30 kN
Force = 4 kN
36 kN
40 kN
30 kN
Force = 2 kN
30 kN
Force = 2 kN
2 kN
40 kN
36 kN
30 kN
43 kN
Force = 2.8 kN

Figure 20-3: SSSF of 7.5:1

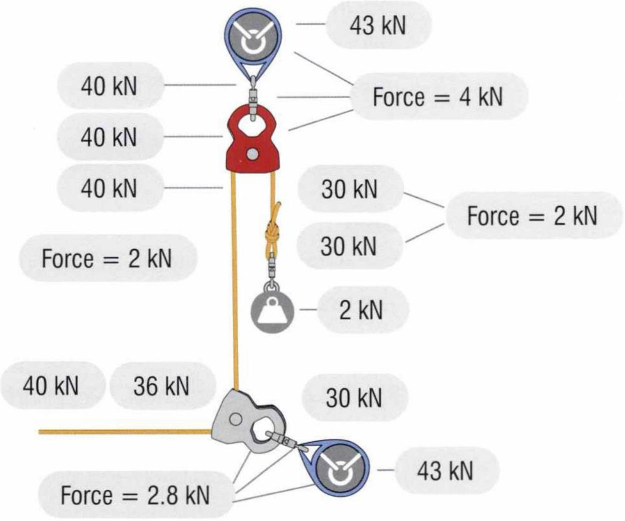

43 kN
40 kN
Force = 4 kN
40 kN
40 kN
30 kN
Force = 2 kN
30 kN
Force = 2 kN
2 kN
40 kN
36 kN
30 kN
43 kN
Force = 2.8 kN

Figure 20-4: SSSF of 10:1

SSSF of 7.5:1. Replacing the carabiner holding the pulley at the top of the system with a 40 kN (8,992 lbf) NFPA general-use carabiner makes the 36 kN (8,093-lbf) pulley the weakest link and would increase the SSSF to 8.75:1. Replacing the pulley with one with a 40-kN (8,992-lbf) MBS would increase it to 10:1 (see Figure 20-4).

The lower change-of-direction pulley has a 90° angle, which puts 1.41 times the load at that point, 2.82 kN (634 lbf). Using the field expedient 1.5 times the force puts it at 3 kN (674 lb) for a SSSF of 10:1. Since this equals the upper pulley, these components do not reduce the SSSF because of the different force at this point.

For the ASTM guide to determining load ratios, see F2491 *Standard Guide for Determining Safety Factors for Technical Rescue Systems and Equipment.*

Next, consider the effects of dynamic loads. Rescue systems are moving systems and this movement introduces dynamic loads to the system in several ways.

THE T-METHOD FOR CALCULATING MECHANICAL ADVANTAGE

The T-method provides an accurate calculation of the forces in the system by determining the units of tension on each segment of rope in the system. The actual value of 1 unit of tension varies as the actual input and output forces change.

The basis of the T-method goes back to basic pulley theory. If there is 1 unit of force suspended on the end of the rope going through a pulley, there must be 1 unit of force on the other end of the rope to hold it in equilibrium. One unit of force on each side puts 2 units of force on the top of the pulley attached to the anchor (or to a Prusik hitch that is connected to a segment of rope) within the

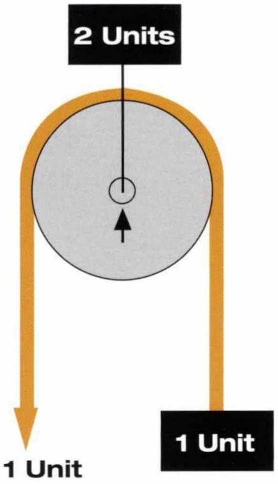

2 Units
1 Unit
1 Unit

Figure 20-5: T-Method Pulley

pulley system. These units of tension are added to the units already on that segment. The sum of the units of tension at the output end is the mechanical advantage of the system.

Applying the T-Method

Step 1: Start at the input end of the haul line, the end where the haul team will be pulling on the rope. The unit of tension at this end will be 1.

Step 2: This unit of 1 follows along the rope until the first pulley is reached. If 1 unit enters the pulley, 1 unit must exit. Like the pulley in the example, the addition of both units (in and out) will produce a force of 2 units at the top of the pulley, which in this example is the Prusik hitch connection to the load line. Remember the 2 units on the Prusik hitch but follow the rope with 1 unit.

Step 3: Continuing out of the pulley, the rope next enters and leaves a fixed pulley. Since this pulley does not move, the force is on the anchor and no units of force are added to the mechanical advantage. Therefore the 1 unit comes out of the pulley and moves down to where the first Prusik hitch is attached. The Prusik hitch attached to the anchor is not loaded when hauling, so it is not part of the system at that time.

Step 4: The M/A pulley is where the mechanical advantage is gained. The 1 unit coming out of the fixed pulley and the 2 units at the Prusik hitch add together, yielding a total of 3 units of tension applied to the rope attached to the load. When comparing the 3 units of tension at the output end to the 1 unit of tension at the input end, a 3:1 M/A is produced.

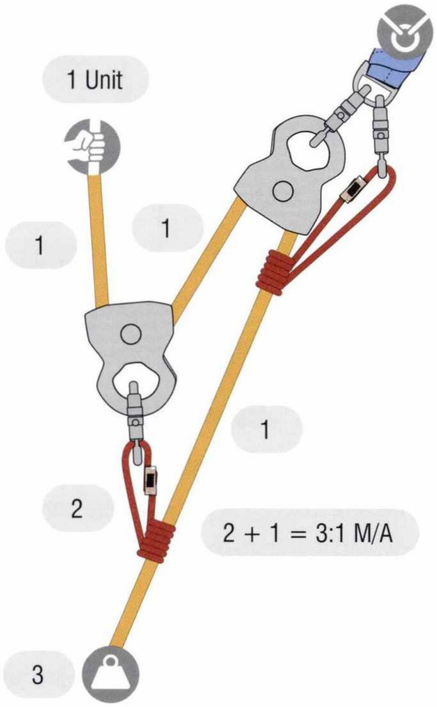


Figure 20-6: Applying the T-Method to a M/A System

Try the T-method on the system shown below. Look at the next page to see if you worked it out correctly.

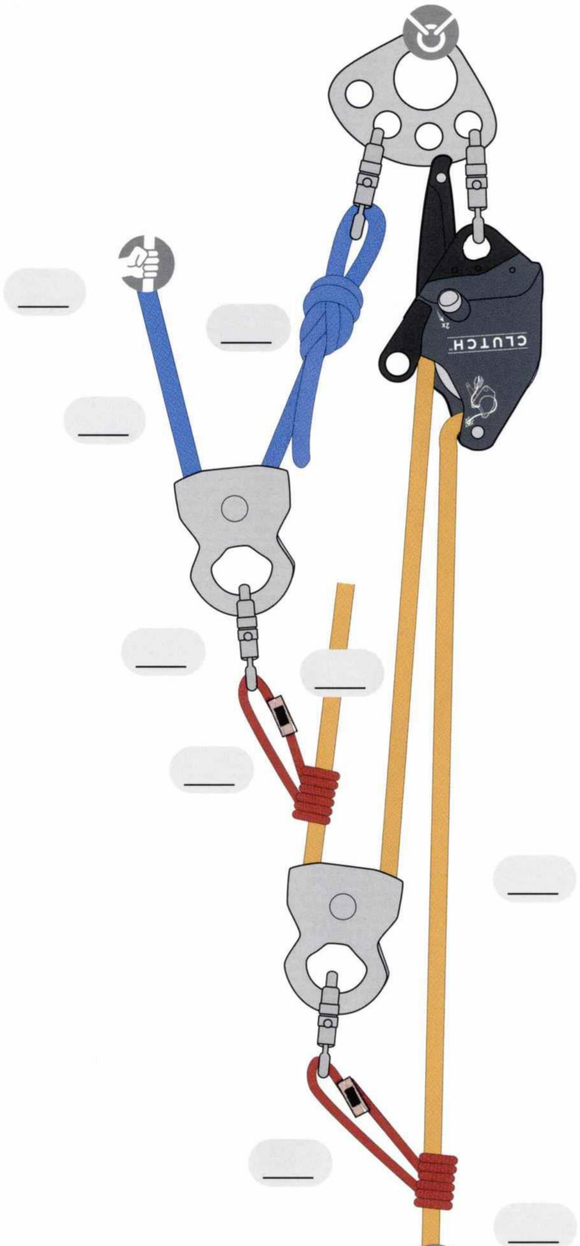
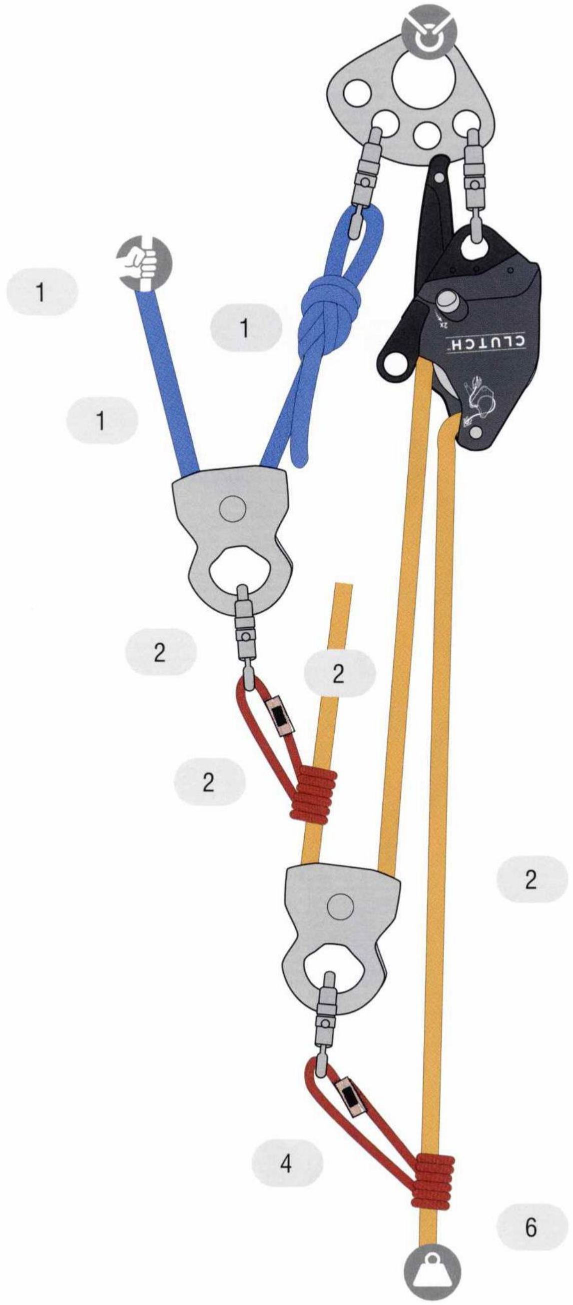


Figure 20-7: M/A to Practice the T-Method



4 + 2 = 6:1 M/A

Figure 20-8: 6:1 Compund M/A System Correct Calculations for the T-Method Example on the Previous Page For more practice, see Appendix D.

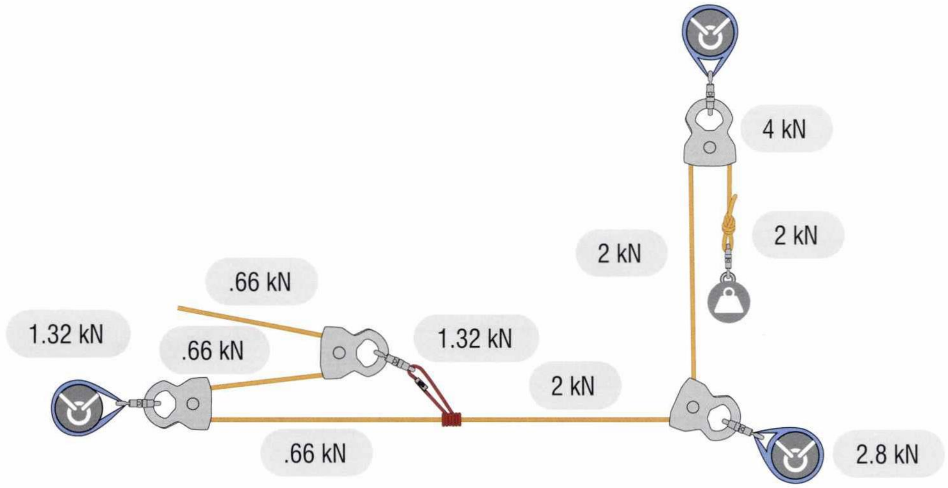


Figure 20-9: System Forces in a Controlled Dynamic Loading

Using the T-Method to Determine the Dynamic System Safety Factor

The actual force for 1 unit of tension is calculated by dividing the weight of the load by the total units of tension at the load. By multiplying that value by the number of units of tension at each point in the system, we can determine the force at each point (see Figure 20-9).

Determining Potential Forces in a System

There is one situation where the weight of the load is not the determining factor of the forces at each point in a raising system. If the load stops moving because it has become stuck or jammed, then forces on the system are determined by the force applied by the haul team. The units of tension can be used to determine the force at each point as a factor of how hard the haul team is pulling.

There are many factors that influence the force of a haul team, such as the strength of the personnel, the gloves worn and how well their feet can grip the surface. Types of surface, such as asphalt, gravel, sand and dirt, have a significant effect on a team's ability to pull.

Field tests have provided some average forces that can be applied to a rescue system to determine the potential forces on the system. One person puts a force of 0.27 kN (60 lbf) on a haul line. This is the sustained force over time, not the short-term tug-o-war maximum force they could apply. Should the load hang up during the raise, the hauler should stop to determine and resolve the problem. Due to the reaction time delay, the force of one hauler increases to an average of 0.89 kN (200 lbf), if only for a moment. A two-person haul team averages 1.67 kN (375 lbf) and a three-person haul team 2.2 kN (495 lbf).

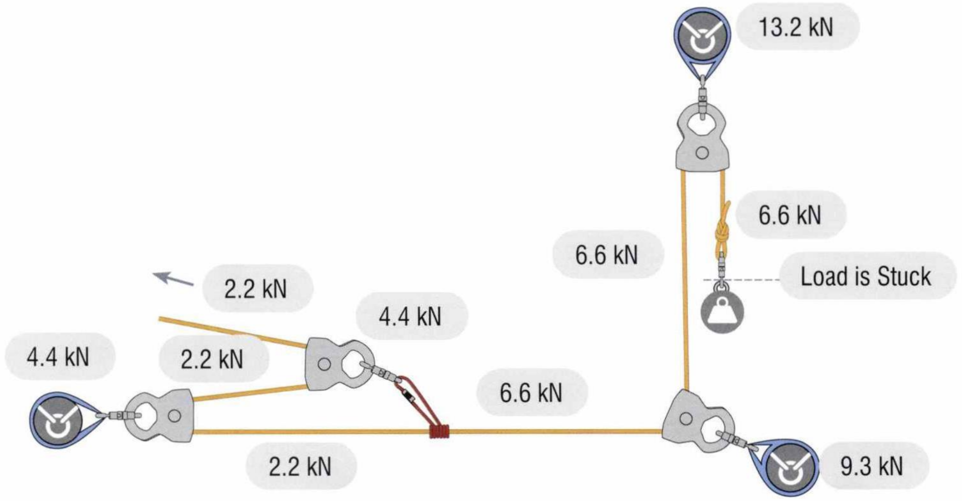

13.2 kN
6.6 kN
6.6 kN
Load is Stuck
2.2 kN
4.4 kN
4.4 kN
2.2 kN
6.6 kN
2.2 kN
9.3 kN

Figure 20-10: System Forces when the Input Force is Increased by the haul team

Using 2.2 kN (495 lbf) as 1 unit of tension for an average three-person haul team, the T-method can be used to determine the potential forces on the system (see Figure 20-10). It should be noted that these forces are not the sustained forces that a haul team applies to a system but the momentary increase in force as the haul team notices that the difficulty of the pull has increased and then stops to find out why. An untrained haul team may just keep pulling harder without understanding the possibly catastrophic consequences of their actions.

Shock Loads

Uncontrolled dynamic loading, or shock loads, occur when the load is dropped onto a slack rope. This could happen when a loaded litter is being placed over an edge and then is accidentally dropped before tension is taken up on the rope. The belay line would receive a shock load if a main line system failure occurred.

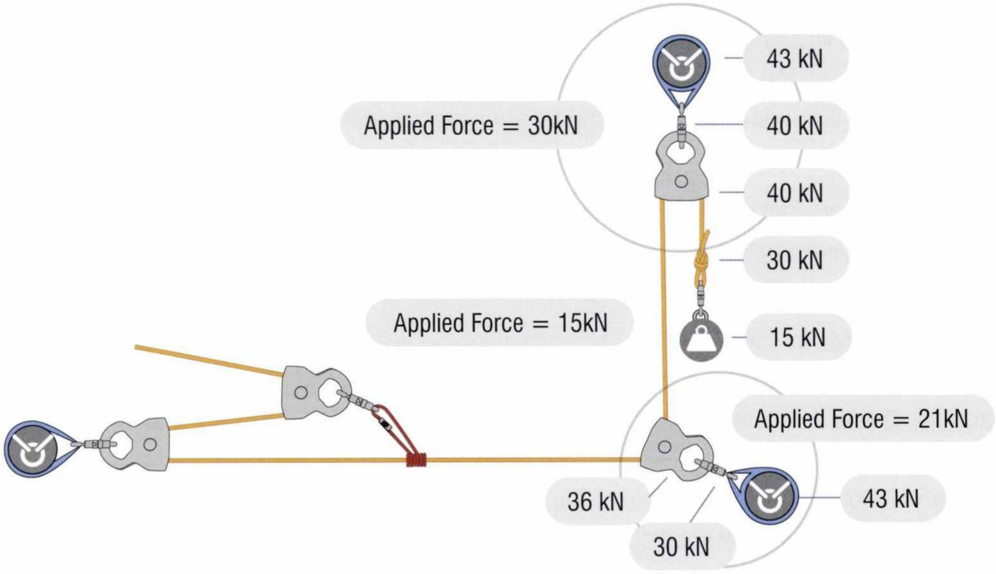

43 kN
Applied Force = 30kN
40 kN
40 kN
30 kN
Applied Force = 15kN
15 kN
Applied Force = 21kN
36 kN
43 kN
30 kN

Figure 20-11: System Forces with a 15 kN Shock Load

The BCCTR Belay Competence Drop Test Method uses 15 kN (3,372 lbf) as the maximum allowable dynamic load. Applying this 15 kN (3,372 lbf) of force to the system in Figure 20-11 places 30 kN (6,744 lbf) of force on the pulley, carabiner and anchor at the top change of direction. The resulting DSSF will be 1.33:1. The actual dynamic forces introduced into the system are impossible to predict and would usually be less. Proper management of rescue systems will limit this loading to manageable levels. Systems can also be engineered to help limit dynamic loading by limiting the amount the load falls before the belay stops it and by also adding shock absorption into the system.

ACTUAL MECHANICAL ADVANTAGE

For simplicity, our system analysis has ignored the friction inherent in the system. Without accounting for friction, our analysis results in only the ***theoretical mechanical advantage***. In the real world, pulleys have friction which adds to the force the haul team must overcome. By including ***pulley efficiency*** in the system analysis, we can use the T-method to determine the ***actual mechanical advantage*** of the system. While the theoretical mechanical advantage is usually close enough, the friction in the system does reduce the effective output of force of the haul team.

There are two primary causes of friction in a pulley. The first is the friction of the sheave rotating on the axle. By using a sealed ball bearing, or an Oilite bushing, this friction can be significantly reduced. Sealed ball bearing pulleys are permanently lubricated and sealed to keep out dirt and moisture, providing a long life. Bushing pulleys use an oil impregnated alloy bushing to reduce the rotational friction on the axle. When new, bushing pulleys are slightly less efficient than sealed ball bearing pulleys. As a bushing pulley wears or as dirt and grime get between the bushing and axle, the pulley's efficiency will deteriorate.

Friction in a pulley is also a result of the rope bending and unbending around the sheave as it goes into and out of the pulley. A softer, more pliable rope tends to be more efficient than a stiff rope. Tests have indicated that the difference in pulley efficiency can be as much as 15%, depending on the stiffness of the rope.

Factors other than friction can decrease the effectiveness of a pulley system. One of the most common factors is not keeping the ropes parallel while pulling. As the haul line moves away from the M/A system, efficiency is lost.

The effect of pulley efficiency on a mechanical advantage system is cumulative; it increases with the number of pulleys in the system. While a single change-of-direction pulley would reduce the output force by 5%, with four pulleys in the system the reduction of the output force approaches 20%. See Figure 20-12 for a T-system analysis of a 9:1 M/A system with pulleys that are 95% efficient and 85% efficient.

Suppose you do not have enough pulleys and need to run the rope through a carabiner to complete the system. The pulley efficiency between steel and aluminum carabiners varies slightly but averages out to about 50%. Figure 20-13 shows using the T-method analysis on a 9:1 M/A to determine the best place to rig the carabiner for the maximum system output.

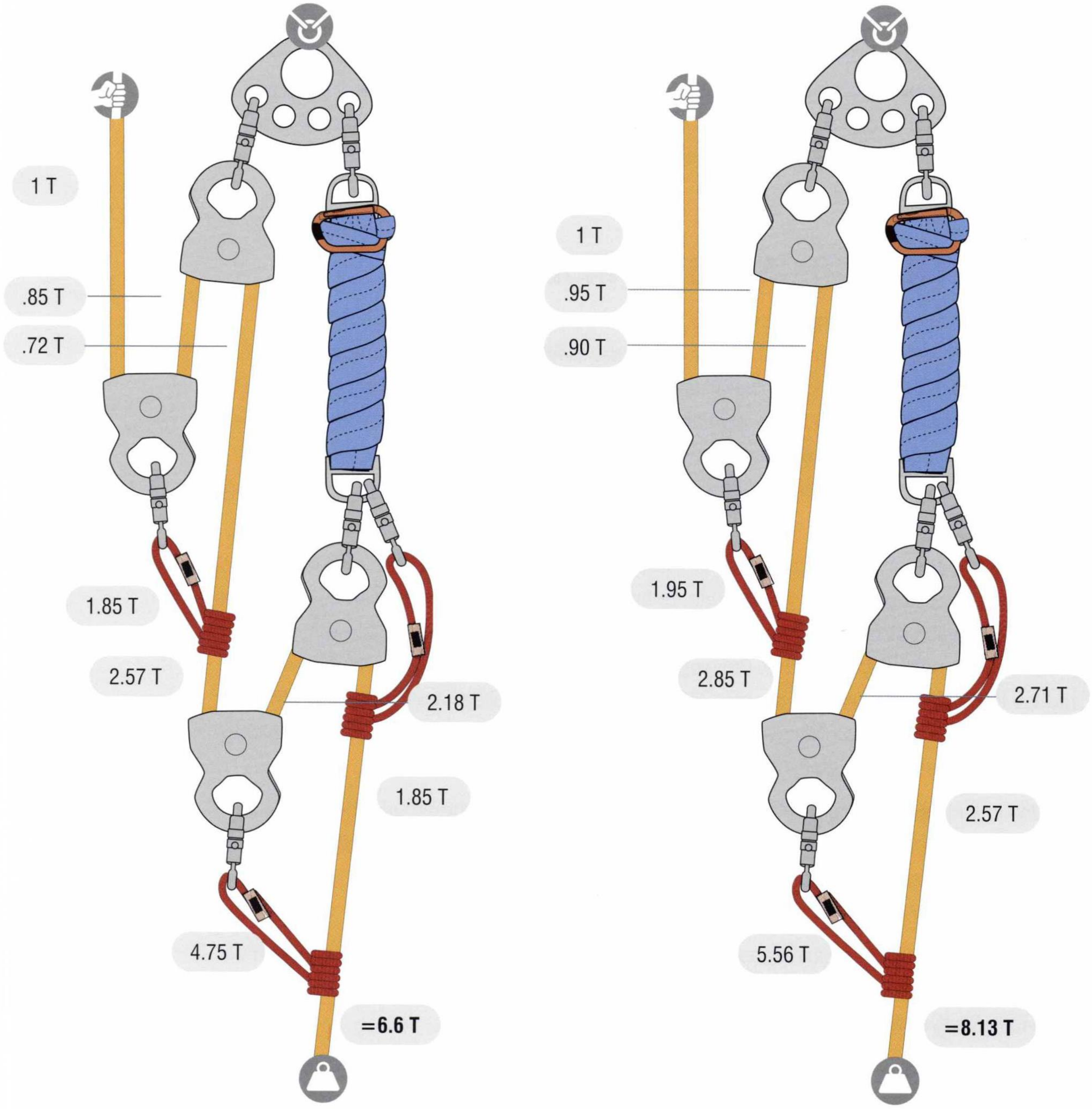

1 T
.85 T
.72 T
1.85 T
2.57 T
2.18 T
1.85 T
4.75 T
=6.6 T
1 T
.95 T
.90 T
1.95 T
2.85 T
2.71 T
2.57 T
5.56 T
=8.13 T

Figure 20-12a:
4–.85 Efficient Pulleys

Figure 20-12b:
4–.95 Efficient Pulleys

Figure 20-12: T-Method Used to Determine Actual M/A

Note: For these calculations, the pulleys are 95% efficient and the carabiner is 50% efficient.

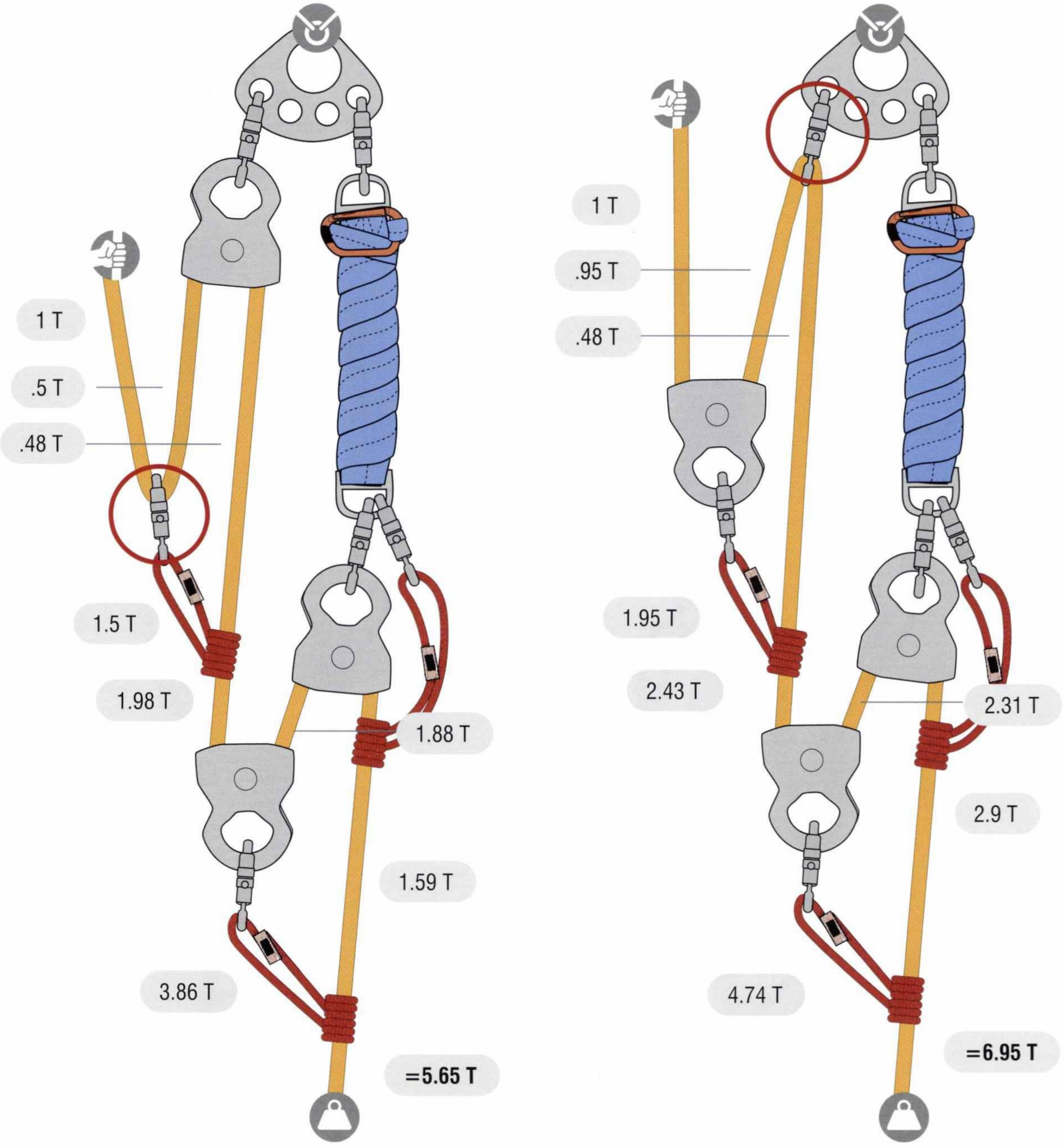

1 T
.5 T
.48 T
1.5 T
1.98 T
1.88 T
1.59 T
3.86 T
=5.65 T
1 T
.95 T
.48 T
1.95 T
2.43 T
2.31 T
2.9 T
4.74 T
=6.95 T

Figure 20-13a:
Carabiner/Pulley in the #1 Position

Figure 20-13b:
Carabiner/Pulley in the #2 Position

Figure 20-13: T-Method Used to Determine Where to Use the Carabiner in a 9:1 M/A

Note: For these calculations, the pulleys are 95% efficient and the carabiner is 50% efficient.

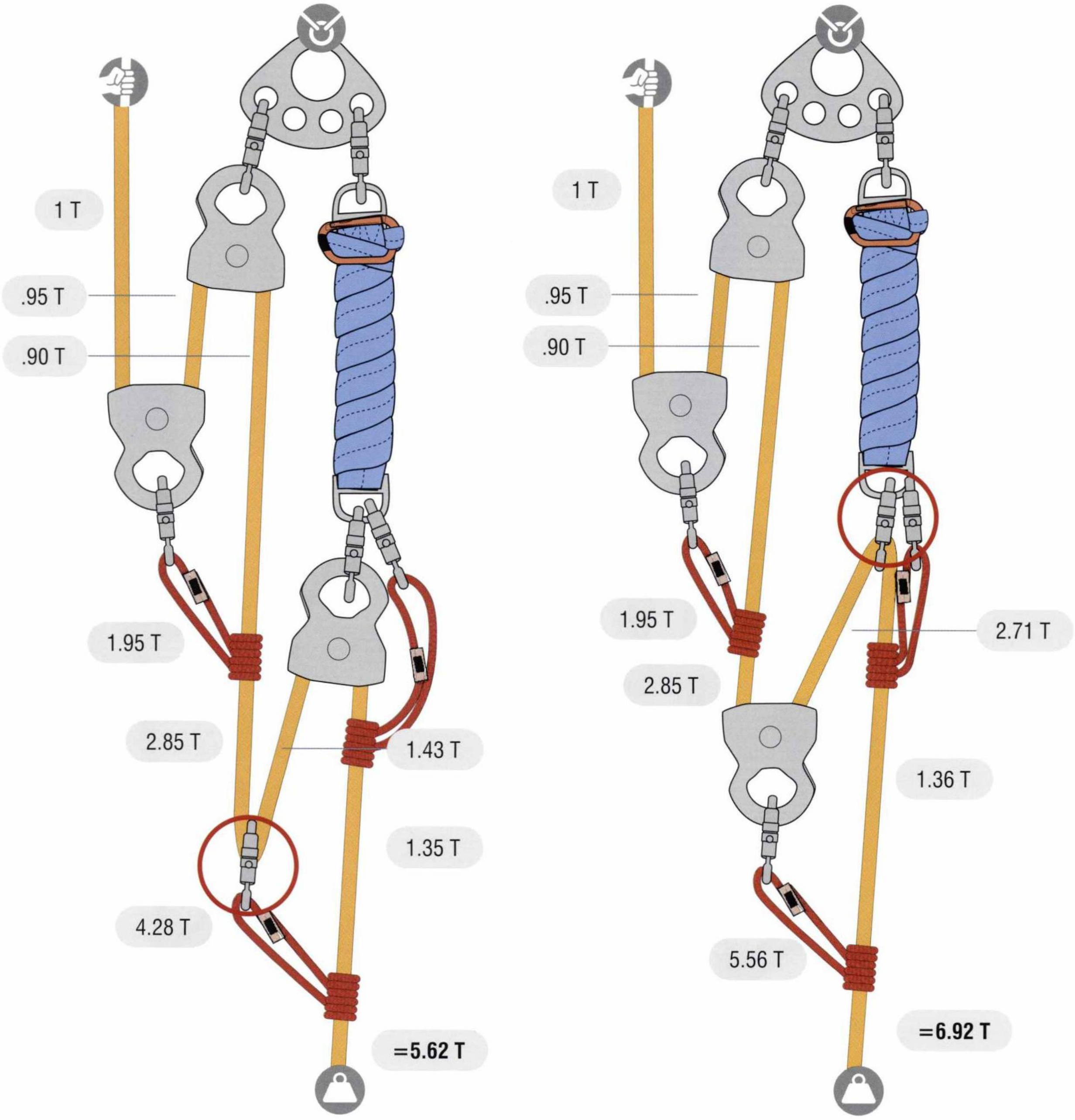

1 T
.95 T
.90 T
1.95 T
2.85 T
1.43 T
1.35 T
4.28 T
=5.62 T
1 T
.95 T
.90 T
1.95 T
2.71 T
2.85 T
1.36 T
5.56 T
=6.92 T

Figure 20-14a:
Carabiner/Pulley in the #3 Position

Figure 20-14b:
Carabiner/Pulley in the #4 Position

Figure 20-14: T-Method Used to Determine Where to Use the Carabiner in a 9:1 M/A

Note: For these calculations, the pulleys are 95% efficient and the carabiner is 50% efficient.

ENVIRONMENTAL CONCERNS

Force-multiplying and strength-reducing situations result from the environmental factors present when rigging the system in the field. If they cannot be eliminated from the system, they must be included in the system analysis.

- Bends in the rope over edges and through carabiners
- Friction
- Rain or water on nylon rope and webbing
- Cross loading on a carabiner
- Force multiplication on pulley and carabiner at a change of direction

HUMAN FACTORS

A system analysis is not complete until the human element is considered. Because the human factor cannot be reduced to numbers, it does not become part of the system safety factor calculation. Thus this human factor is often ignored by rescuers interested only in how much load the system can handle.

The human factor must take into account: the level of training and experience of the team, the complexity of the systems and the ability of both the systems and the rescuers to function when conditions become a distraction. Darkness, rain, cold, wind, emotional shock and pressure to hurry (approaching fire, rising water, deteriorating patient) all reduce the rescuer's level of performance. The simpler and more foolproof the systems are, the less chance human error will be the cause of a system failure.

SELECTING A SYSTEM SAFETY FACTOR

How much safety is enough? How much safety is too much? Should there be different safety standards for training sessions than for rescue operations? How much redundancy can be added before the system stops functioning? There are a lot of ways to look at selecting an organization's minimum system safety factor.

To date, there is no standard mandating what the SSSF should be. For many years, mountain rescue teams have used a 4:1 SSSF successfully. We have heard both 5:1 and 10:1 SSSF suggested for rescue teams. Some fire service teams use 15:1 SSSF because the committee drafting NFPA Standard 1983 used a factor of 15 to determine tensile strength performance requirement for new general-use rope. The 15:1 ratio was never intended to apply to the entire rescue system, and if you do the math, it is almost impossible to achieve. The CMC School has chosen a 10:1 SSSF as a guideline for our systems.

A minimum DSSF Factor of 2:1 has been suggested, more as a point to begin the discussion of what factor would be appropriate for rope rescue systems. Since an industry consensus does not exist for a minimum SSSF and until the relationships between dynamic and static system performance are better understood, it would be premature to decide on an industry

Key kNs

These are the most common strengths used when calculating system strength:

40 kN: NFPA requirement for general-use rope, carabiners.

36 kN: NFPA requirement for general-use pulleys, anchor plates.

22 kN: NFPA requirement for technical-use carabiners.

20 kN: NFPA requirement for technical-use rope. OSHA 5,000 lbf (22.2 kN) requirement.

18 kN: NFPA requirement for technical-use pulleys.

Rope Rescue Math

For easier calculations, numbers can be rounded off.

Example:

A mass of 2.2 lb is 1 kg, so a 220 lb person would have a mass of 100 kg.

With gravity at about 10 m/s^2 our 220 lb person would be a 1 kN load.

A rescuer with a patient would give us about a 2 kN load.

standard minimum DSSF, and the two may not have a relationship at all.

Whatever number you select, it is most important that you understand the concept and can apply it to your equipment and systems, both in setting up your team standards and on-scene evaluations.

Equipment standards such as NFPA 1983 are on regular revision cycles (typically 5 years). This means that every five years the committee is tasked with taking a fresh look at the document and to incorporate input from the end user community as well as lessons learned since the last revision cycle. The most common equipment standards have been around for decades and have matured and been refined through the course of numerous revision cycles. End users, equipment manufactures and testing laboratories have a better understanding of the performance requirements of equipment now, more than ever. Since 2001, equipment manufacturers who certify equipment to NFPA 1983 are required to be registered to ISO 9001, which requires the establishment of a robust quality management program.

The industry now has a substantial track record of equipment use. Equipment performance requirements and test methods have been improved considerably throughout the years and manufacturers now maintain robust Quality Control programs. This allows the rope rescue practitioner to take a fresh look at how they rig rope systems. In other words, instead of asking "how strong can we build the system?", we can ask "is this system capable of the task?"

Identifying a static safety factor (SSF) is as straight forward as determining the ratio between the weakest link in the system divided by the anticipated load. Having an understanding of potentially worse case dynamic loads for a truly worst case system failure will allow for the determination of either: 1) isolating the risk and making changes to the rigging, or by 2) incorporating load limiting features to your systems to prevent a component from breaking.

Let's look at a few examples.

Raising systems

Once the load is lifted and fully supported by the raising system, a potentially worst case scenario could occur if the litter (load) were to get hung up while the haul team continues raising. By using the T-method, one can determine which point in the raising system sees the highest load. Using a conventional 3:1 haul system as an example, the component that sees the greatest dynamic load (during the raise) is the haul rope grab. Testing of some mechanical rope grabs indicate they can sustain high loads, but will sever the rope without warning. Testing on 8mm triple wrap Prusik hitches indicate that they tend to slip at an acceptable threshold. The better choice to mitigate risk in this example would be to use a triple wrap 8mm Prusik as the haul cam in the raising system due to is capability to slip when overloaded.

Lowering system

The original belay competency test was formulated to simulate a worst case scenario during an edge transition:

- A rescue system set up relatively close to the edge with 3m of rope
- A main line failure occurs during an edge transition resulting in a 1m drop on a non-tensioned belay line
- The original performance criteria based on a 2kN load included a maximum system extension (stopping distance) of 1m and a maximum peak impact force of 15kN

The current NFPA criteria uses a 60cm drop on 3m of rope. Plus a maximum system extension of 1m meter and a maximum peak impact force of 15kN when using a 2.7 kN load. Therefore, a certified belay device must be designed as such to limit the peak impact force to 15kN.

Dynamic forces produced by a falling load are usually greater than anticipated static loads due to the additional force exerted by gravity. These forces peak for a brief period during the arrest phase. There are several variables and factors that go into calculating peak arrest forces. However, if the freefall distance can be minimized by proper rigging techniques, a conservative multiplier of 2.5 applied to the static load (potential energy) should provide a conservative estimate of peak impact forces (kinetic energy). For example, a 2.7kN load (patient plus the rescuer and equipment) when subjected to the belay performance criteria will yield an estimated peak impact forces of 6.75 kN. This is well below the threshold of a certified belay device.

A common error that some people make is to use the rated breaking strength of a component as the sole determining factor of the integrity of the system, where in actuality rope damage can occur far below this threshold. In other words, a 10:1 SSF may give you a false sense of security if rope damage or equipment deformation occurs at much lower forces. A practical method of rigging your systems should include the determination of the maximum potential load that can be placed on the system and to rig accordingly. Factor in load limiting equipment and make sure that all components are above this margin. Doing so will provide you with a better understanding of the capabilities and weaknesses of the system.

Notes

PART
05
Individual Skills

CHAPTER
21
Rappelling

LEGEND: Anchor Grip Load

TERMINAL LEARNING OBJECTIVE

The student will demonstrate how to descend a rope using a descent control device from different edge conditions and passing a knot.

ENABLING LEARNING OBJECTIVES

1. Describe the different methods of deploying the rappel line
2. Describe how to construct a fixed rope system
3. Demonstrate how to rappel over a parapet
4. Describe how to set up a rope retrieval system
5. Describe different methods to belay a rappeller
6. Demonstrate a tactical rappel
7. Demonstrate how to pass a knot on rappel

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.2.12 | 5.3.10 | 5.3.11

Rappelling lets the Rope Rescue Technician access terrain that is too steep to walk on safely or impossible to walk down at all. This chapter will cover the fundamental techniques that apply to all rappels. Later in this chapter we will provide tips on using the CLUTCH, and also the Figure 8 Descender, for rappels. See Chapter 16 for rigging the CMC 3D and Brake Bar Rack.

DEPLOYING THE RAPPEL LINE

Start by connecting the rope to a secure anchor. If you are rappelling down to a patient or planning a pick-off, make sure the anchor is suitable for a two-person load. If the rappel line may become part of the litter system, then the anchor should be strong enough for that. If this is a training or tactical situation, using a contingency anchor as shown in Figure 21-1.

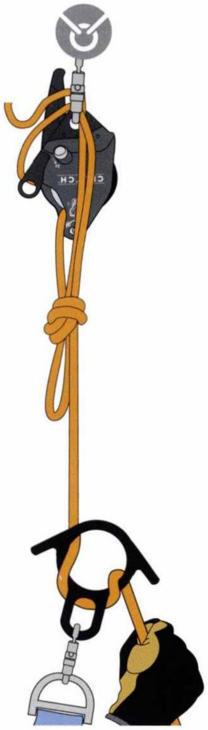


Figure 21-1: Contingent Rappel Anchor

When the rope is secured to the anchor, the rope can then be used to approach the edge. This can be done with a Prusik hitch or mechanical rope grab self-belay, or if you will be the one on rappel, you can set up your descender and belay. This will provide a belay for fall protection when verifying the subject's location and for when you deploy the rope.

Throwing the rope is not a good procedure for most rescues for the following reasons:

- The rope may hit the subject
- The rope may knock rocks or other debris down on the subject
- The rope may be grabbed by the subject, which can stop a rappel
- The rope may end up in a tangle at the bottom
- The rope may get tangled on the way down

The last situation becomes more of a problem as the descent slope becomes less vertical. For example, on a brush or tree covered hillside, the rope may not land on the side of the bush or tree that you need to be on during the rappel. Futhermore, the rope cannot be deployed as far and the tangle will have to be cleaned up before you can continue the rappel.

For most situations the rescuer can keep the rope bag with them as they rappel. If the bag is hanging slightly below the rescuer, the rope will feed out during the descent. On a gentler slope, the rope bag can be worn like a pack. If the rope does tangle coming out of the bag, the bag can always be dropped.

On a structure or a vertical cliff, the end of the rope can be lowered, keeping the bottom end just off of the ground. This is a good practice for rappel training since it lets the rope unwind after successive rappels. On a rescue, lowering the rope allows it to be kept away from the subject and also avoids the risk of hitting the subject with a thrown rope.

If the rope will be used later for the main line or the belay line, sufficient rope will need to be available at the anchor to set up the mechanical advantage system or the belay. Connect the rope to the anchor, leave enough slack, and then connect it into a Prusik hitch. The hitch becomes the ratchet for the main line or a second hitch can be added to rig a tandem Prusik belay.

If the rope needs to be thrown, a well-designed rope bag prevents tangles and allows for a very accurate throw. When the bag hits the bottom, usually the excess rope will stay in the bag, which protects it and keeps it clean.

If there is a chance of the rope bag hanging up when the rope is pulled back up, the bag and knot should be removed, or the rope can be dropped and bagged at the bottom.

Without a rope bag, the rope needs to be uncoiled and flaked into a pile. Next, loop several coils into your hand and throw the coils, letting the rest of the rope feed out from the pile. Look before throwing to make sure no one is in the way. To warn people, yell "rope." Another method that CMC's instructors prefer is to toss the middle coils of the rope first, then the coils near the end.

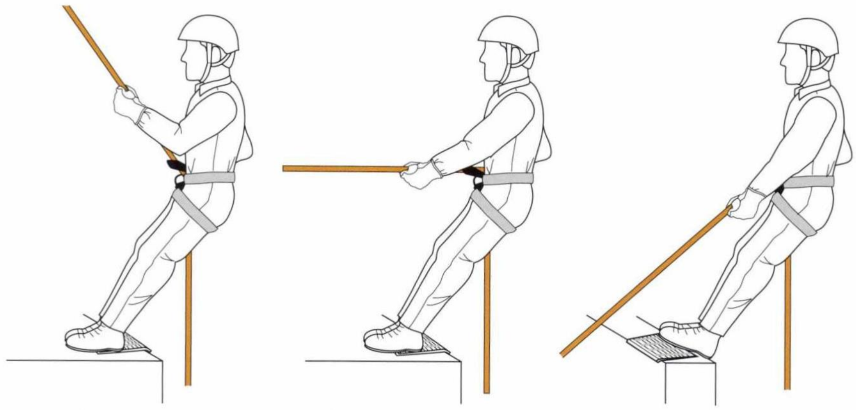
On a tactical rappel, the falling rope bag or a hanging rope can announce an officer's intentions. Once again, the solution is to keep the rope bag with you and deploy as needed. Getting in position and then dropping the bag will put the officer in position for a fast exit down the rope or the ability to use a bottom belay for either protection or emergency lowering.

The illustrations on page 220 and page 221 show the rappels with the Figure 8 descender, but the same techniques apply for the 3D, Brake Bar Rack, I'D, Scarab® and other descent control devices. In some of the illustrations, we have left off the belay for clarity and because of the several types that could be used.

TAKING THE FIRST STEPS

Depending on the type of edge and the angle of the rope in relationship to the edge, the start of a rappel can be the most exciting part. The unstable feeling at the edge plus the realization that your life is committed to the rope and the equipment can be unnerving for the beginner. Add some height to the rappel and it can be a little unnerving even for the experienced.

Before you step over, check everything again, from the anchor to your harness. Use the buddy system and check your belayer while they check you. Use the touch system and touch everything you check to make sure that you really checked it. Is the rigging done right? Carabiners locked? Edge pads in position? Do you have the equipment with you that you will need below? If so, then you are ready. If you have a belayer, say "on belay" and wait for their answer, "belay on." When you start, tell your belayer that you are "on rappel" or "rappelling."

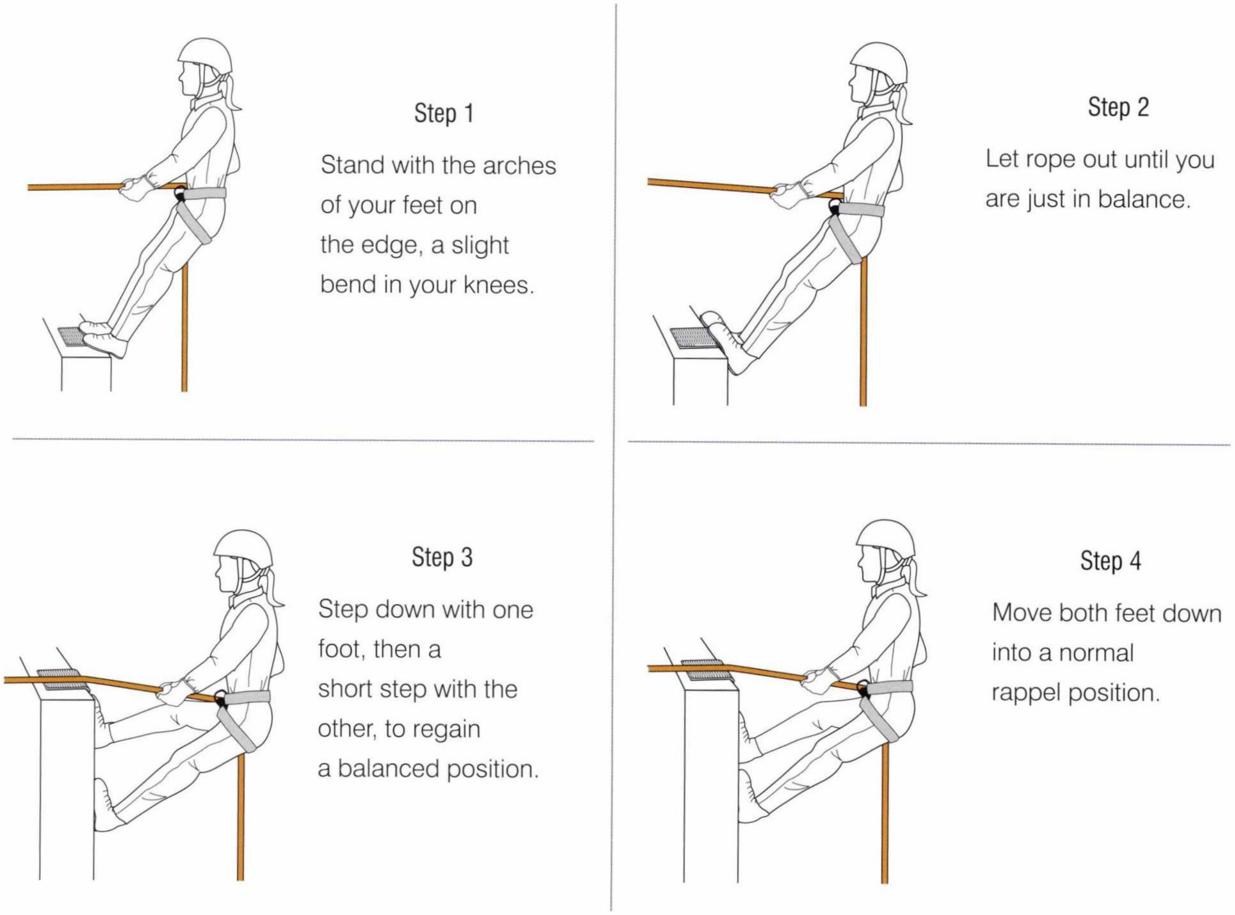


Easy Start:
The anchor is above.

More Difficult Start:
The anchor is waist level.

Most Difficult Start:
The anchor is low.

Figure 21-2: Different Start Positions



Step 1

Stand with the arches of your feet on the edge, a slight bend in your knees.

Step 2

Let rope out until you are just in balance.

Step 3

Step down with one foot, then a short step with the other, to regain a balanced position.

Step 4

Move both feet down into a normal rappel position.

Figure 21-3: Negotiating a Difficult Start

Negotiating a Difficult Start

If there is a 90° building edge and the anchor is waist high or lower, start by standing with the arches of your feet on the edge (see Figure 21-3). Rotate back until you feel at the edge of your balance or the need to step down. At that point take a small step or two to regain equilibrium. If you step too soon, your feet may slide down below you and your face will hit the edge. If you rotate too far, you may invert onto your back with a chance of hitting your head.

CMC PRO TIP

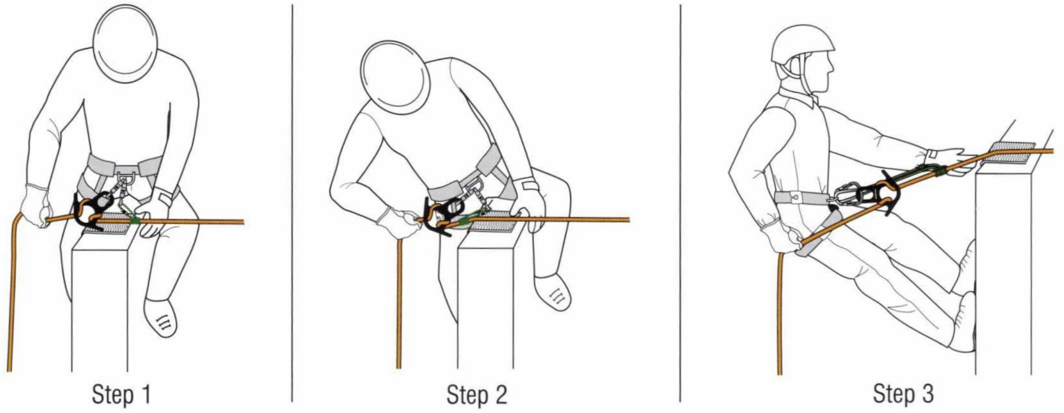
To quickly check to make sure a carabiner is closed and locked, squeeze it with your hand. Check auto-locking carabiners as well; a piece of webbing might keep them from closing and locking.

If you do slip, place your feet against the wall and slowly let out on the rappel rope. As your feet gain more traction, push out into the normal rappel position and continue the descent. If you start to rotate backward, bend your knees. This moves your center of gravity closer to the wall.

If the start is very difficult, such as from a wall on top of the building, try rolling off. Start by sitting with your legs hanging off. The descender should be in position to just clear the edge with all the slack out of the rope. Hold the rope tight with your brake hand and grab the edge with your free hand. Turn your legs into the wall while leaning forward. Use your free hand to lower your weight onto the rope. Begin to push away from the wall with your feet as you let rope out with your brake hand until you are in the rappel position. Do not let the rope run over the hand that is holding onto the wall.

If the roof has a parapet, you can straddle the wall (see Figure 21-4). The procedure is essentially the same. A straddle feels more secure, but getting your trailing leg over the wall tests your flexibility.

GOOD RAPPEL TECHNIQUE


Step 1

Step 2

Step 3

Note: Pre-measure to make sure the descender and Prusik hitch clear the parapet edge before your weight is on the rope.

Figure 21-4: Sitting Start off of a Parapet Wall

Proper rappel technique is a steady, smooth walk down. Legs should be 90° to the surface. On a vertical wall, bend at the waist, so your body is like an "L" and keep your feet up high, almost near waist level, to prevent them from slipping. Hanging from the rope creates a pendulum that forces your feet into the wall giving you traction. Remember, spreading your feet about shoulder width apart provides the most stability.

Fast rappels heat up the rope and sudden stops shock load the entire system from the anchors down to your body. Very fast rappels are hard on the rope and lead to accidents. They should be avoided unless there is an overriding reason to minimize time on the rope. Bounding rappels can lead to a loss of control.

The brake hand (for most people this is the right hand) controls the descent by using the friction of the descender. The left hand can hold onto the rope above the descender for balance. Do not try to control the descent with the left hand as it has little braking strength and can easily be burned by the rope. The left hand would also control any self-belay. If the left hand is the strong hand, just reverse the directions, although rescuers should be able to rappel with either hand as the brake hand.

If there is anyone below, pick a descent path well off to the side to avoid knocking rocks or debris down onto them. Remember, a rock will not always go straight down; rather it follows the fall line with plenty of bouncing and ricochets.

RETRIEVABLE ROPE RAPPELS

The rappel may be set up to pull the rope from the bottom. This is useful if making a multiple rappel descent or if rappelling down over an obstruction on a back-country search. There are several ways to set this up that vary between efficiency and the need to leave equipment behind. Each requires a rappel on two ropes, which will have significantly higher friction than rappelling on a single line.

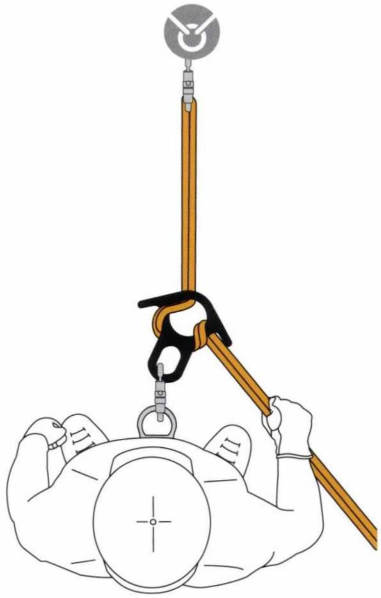


Figure 21-5: Double Rope for a Retrievable Rope Rappel

The most efficient way is to double the rope in the middle and clip it into the carabiner at the anchor (see Figure 21-5). Another method is to thread the rope through a less expensive rappel ring. It is possible to thread the rope through the anchor web and not leave any hardware behind. This is usually a one-time use since pulling the rope down will damage the web. The rope can be wrapped around a tree or other similar anchor point if you are sure that it will not harm the rope during the rappel. The higher levels of friction in the latter two methods can make the rope difficult or impossible to retrieve.

Tie both ends of the rope together with a Figure 8 knot. This creates the safety knot that will hopefully prevent the rescuer from rappelling off the end of the rope. John Dill, Yosemite Search and Rescue, suggests an improvement by clipping a carabiner around one of the ropes and attaching it to the harness (see Figure 21-6). The carabiner is inside the loop made by the knot, and this set up does not rely solely on the safety knot jamming to keep the descender from going off the end of the rope.

Rig the descender on both of the lines and hold on to both of the lines with the braking hand. Remember, the rope is not tied to the anchor.
If you let go of one side, you will lose control of the rappel. If the ends are tied together, this may help prevent a disaster. When off rappel, untie the bottom knot and pull on one end of the rope until it falls. Get out of the way so that no one gets hit by the rope or anything that it knocks loose on its way down.

The rappel is not backed up just because the rope is doubled. Failure of the anchor or a break in either of the lines is just as serious a problem as on a single-line rappel. The need for a belay is the same. Attach a self-belay by tying the Prusik hitch around both ropes or use a Petzl Shunt. A bottom belay works the same as with a single rappel line.

BELAYING THE RAPPEL

A belay helps prevent an accident. If there is a rigging mistake, if an anchor fails or if your brake hand slips, your belay saves you from disaster. Whether training or on a rescue, if there is any potential for someone falling, there should be a belay. This is probably even more important on a rescue due to all of the potential distractions.

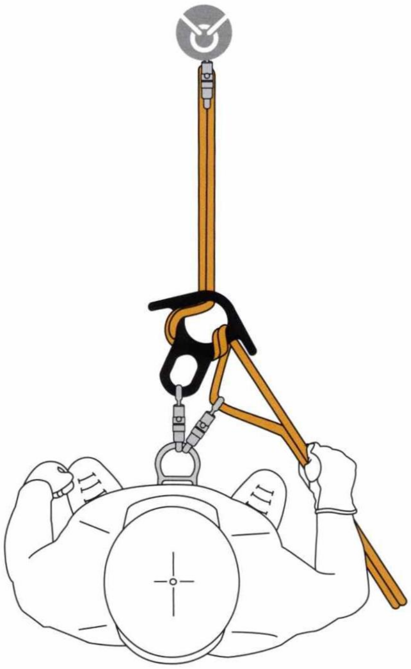


Figure 21-6: Retrievable Rope Rappel with a Carabiner for Additional Safety

Terminology

In describing the level of protection afforded by different types of belays, it is important to understand the following definitions. The types of belays are listed in descending order of the level of protection that they provide.

Independent Belay – An independent belay provides the highest level of protection because it does not share any components with the rappel system. An independent belay has a separate anchor, rope and person to manage it.

Safety Line – This is an independent belay operated by the rappeller. It protects against the failure of the rappel system but does not have a separate person managing the belay.

Bottom Belay – A bottom belay uses the rappel rope and anchor but is managed by a separate person stationed at the bottom of the rappel. This is a conditional belay that does not protect against failure of the rappel line or anchor.

Self-Belay – The lowest level of belay protection, the self-belay attaches to the rappel line and is operated by the person on rappel. This is a conditional belay that does not protect against failure of the rappel line or anchor.

Belays can also be classified based on the action required of the belayer.

Automatic Belay – The belay activates automatically without any action required from the belayer. This is the preferred type of belay since it will work even if the belayer makes a mistake or is unable to respond. This is referred to as passing the whistle test; if the system operators let go when the whistle blows, the system will stop.

CMC PRO TIP

The CMC School and the International Technical Rescue Association both recommend an independent belay when teaching rappel skills. See Chapter 34 for using a Safety Line for a self-belay while on rappel.

Manual Belay – An action from the belayer is required for the belay to operate. If the belayer does not respond or makes the wrong response, the belay will not work. A slow response could result in a shock load to the system.

INDEPENDENT BELAY

The belay system that CMC teaches for lowering a litter is the same system as an independent belay for protecting a rescuer descending on rappel.

Because it is entirely separate from the rappel system, it protects the person on rappel from human and rigging errors anywhere in the rappel system. It also provides the option of using the belay line to lower or to raise the person on rappel. If the rappeller begins to have trouble controlling the descent, the belay can share part of the load.

The disadvantages of the independent belay are the extra equipment and personnel required. Two complete systems and two rescuers are needed for the belay to be fully independent. Good communication must be maintained between the belayer and the rappeller to allow the latter to control the rate of descent.

Tandem Prusik Belay System

The standard rigging used by the CMC School for a Tandem Prusik belay is two triple-wrap 8 mm Prusik hitches. The same setup is used on $^{7}/_{16}$ in and $^{1}/_{2}$ in (11 mm and 12.5 mm) ropes, and for belaying rappels as well as rescue systems. For best performance, the Prusik hitches need to be separated by about four inches. To do this, use Prusik loops that are of different lengths. The shortest one should be just long enough to fit in front of the change-of-direction pulley used on the raising belay. If each size loop is a different color they will be easier to tell apart. Use a load release strap or load release hitch to connect the two Prusik loops to the belay anchor.

The Tandem Prusik belay operates in either direction without any changes, either for a rappeller or a climber. Unlike the mechanical belay system, the Tandem Prusik belay is not ready to lower a person on rappel but will hold the person's weight until a descender is rigged onto the belay line.

During operation, the belayer tends the Prusik hitches with one hand and pulls the rope through with the other. For the most reliable performance, place the rope bag (or the rope flaked into a pile) off to the side, so that the rope enters the Prusik hitch at an angle. For more information on the Tandem Prusik belay, see page 151.

Mechanical Belay Devices

The CLUTCH and MPD, the Traverse Rescue 540° Rescue Belay, and the Petzl I'D can all be used to protect a rescuer on rappel. The CLUTCH, MPD and 540° are designed to let rope out and then react automatically when a belay is needed. All four are size specific for the rope diameter so make sure you match the unit to the rope.

The CLUTCH, MPD and the I'D have the advantage of being able to lower the rappeller if needed. This can be helpful during training sessions if the rappeller is having trouble controlling the rappel.

SAFETY LINE

A safety line or independent self-belay consists of a Prusik hitch or belay device on a second rope that is attached to a second anchor. Some departments have a policy that requires the use of two ropes at all times. The safety line belay allows a person to rappel without needing a second person to tend the belay. Because the self-belay is attached to an independent line, the rescuer is protected against failure of the rappel system.

A safety line is the standard procedure for the Rope Access Technician when ascending or descending the working line. For greater efficiency, a mobile fall arrestor, or other back-up device, can be used. See the Rope Access chapter for more detail on using a safety line.

BOTTOM BELAY

Named for the location of the belayer, the ***bottom belay*** uses the rappel system as the belay system. It protects against the rappeller losing control, either from the brake hand becoming overheated or slipping off the rope. It does not protect against the failure of the anchor, the equipment or a mistake in rigging. The belayer stands at the bottom and holds the rope with both hands. Because they can use their full body weight, they can pull harder than the rappeller can. Also, their grip will

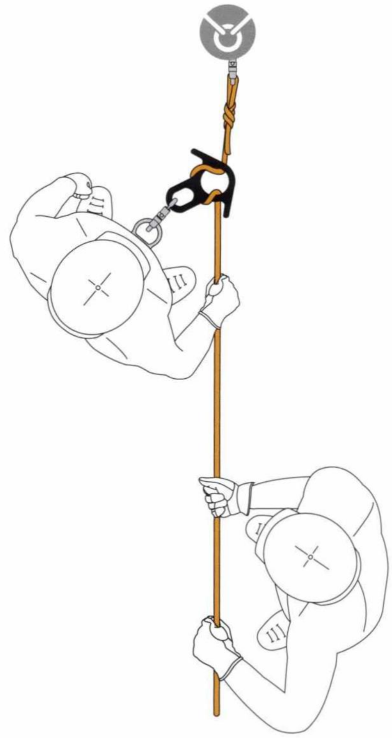


Figure 21-7: Bottom Belay for a Rappel

be more secure since the rope is not moving through their hands building up heat. **While effective for belaying a person on rappel, the bottom belay may not be able to arrest a falling rescue load.**

A bottom belay is very effective. In fact, the rappeller can let go of the rope and let the belayer control the descent. With good communication, the rappeller can descend hands free. This can be an important advantage in a rescue where the hands need to be free for the subject or in a tactical situation where a weapon might be carried.

Using a bottom belay, the belayer can pull the rappeller away from the face of the building or cliff. This shifts control from the rappeller to the belayer but may have an advantage if the rappeller needs to avoid the face of a cliff or land some distance away from it. Care must be taken not to inadvertently pull the rappeller away from the surface. This can happen if the belayer moves away from directly below to avoid any rockfall created by the rappeller. If there is a rockfall hazard, the belayer will need a sheltered position that still allows a view of the rappeller.

PRUSIK HITCH SELF-BELAY

A Prusik hitch self-belay protects the rappeller against losing control of the rappel. Like the bottom belay, it does not protect against the failure of the anchor, the equipment or a mistake in rigging. There are several systems used, each requiring reactions by the rappeller.

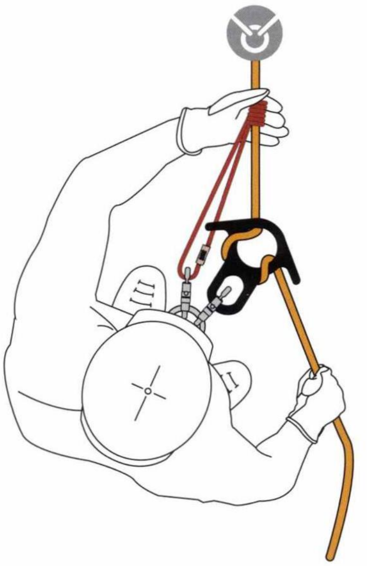


Figure 21-8: Prusik Hitch Self-Belay for a Rappel

The simplest method to set up a self-belay is to attach a Prusik above the descender and clip it into the harness. One hand is the brake hand that controls the rappel and the other slides the Prusik down the rope. If the rescuer loses control of the rappel, the Prusik should grab the rope and stop them. Like all Prusik-hitch-based systems, the self-belay is dependent on selecting a Prusik material that will grip the rope reliably when the rappeller lets go of the hitch.

It also depends on the rappeller letting go of the Prusik hitch. The loss of control of the rappel may cause the falling person to panic and the instinctive reaction is to grab the rope. If that hand is tending the Prusik hitch, it is possible to pull the knot down the rope with you. The correct response is to let go of the Prusik hitch, allowing it to grab the rope. It has been our experience in classes that the student will most often let go of the Prusik hitch if the rappel begins to move too fast and heat builds up in the hand.

Proper operation of the Brake Bar Rack uses one hand on the bottom bar to spread or push together the bars, and the other holding the rope. As a result, a hand is not available to tend the self-belay. The hand that controls the spread of the bars can be used for the belay, but then the rescuer has to stop each time they want to adjust the bars. Another option is the tactical rappel.

Stuck Prusik Hitch

If the self-belay activates, either intentionally or unexpectedly, the rescuer's weight will have to be unloaded from the Prusik hitch to loosen it. A hard pull on the Prusik hitch with both hands may get it to slide. An extra Prusik or ascender, along with an etrier or foot sling, can be used to take the rescuer's weight off the hitch in order to free it. Attach the etrier above the descender and stand up as discussed below.

What if you do not have extra gear or you are not strong enough to free the Prusik hitch by brute force? The following procedure will get you out of the stuck Prusik. We recommend practicing with someone experienced in this technique and practicing close to the ground until you are proficient with the procedure.

Step 1: Lock off the descender with a single wrap.

Step 2: Form a bight in the rope below the descender and put one foot in the bight with the knee bent.

Step 3: Bring the rope from the bight over the top of the descender, still bending the knee, and then wrap the rope two more times around the descender for a total of three wraps.

Step 4: Stand up in the bight to take the weight off of the Prusik hitch. Loosen the hitch and slide it down the rope.

Step 5: Sit back down in the harness. Unlock the descender, making sure not to load the Prusik hitch.

BELAYER SAFETY

Does the belayer need protection from falling? When working in the vertical environment, a belay station placed near the edge may expose the belayer to a fall. The sudden pull on the belay line when stopping an out-of-control rappeller could knock a belayer off balance. This risk usually occurs at the top when the belayer is tending an independent belay, but a belayer working a bottom belay should also evaluate the exposure to falling.

During a rescue, we recommend the belayer use an anchor separate from the system anchors. If the system should fail, the belayer would not be pulled along after it. This is much less likely in a rappel situation, but if there is the time to set this up, it increases the level of safety. If time considerations or location makes a separate anchor impossible, an extension from the rappel anchor will do.

When operating a bottom belay, there is also the exposure to any debris that is knocked down during the rappel. Wearing a helmet should be obvious, but the belayer may want to move away from the fall line or find shelter under an overhang.

THE TACTICAL RAPPEL

The tactical rappel allows the rescuer to rappel with one hand free and still use a Prusik hitch self-belay. It also allows the rescuer to let go of the rappel line without locking off the descender. The Prusik hitch supports the rescuer's weight, but since it is on the back side of the descender, it is much easier to unstick to resume rappelling again. The tactical rappel essentially creates an auto-stop descender out of a non-auto locking descent control device.

Several years ago, cavers began experimenting with a Prusik hitch or autoblock located below the descender and attached to the leg loop of their harness. After experimenting with the technique, we extended the descender so that we could attach a Prusik hitch to the waist D-ring. This provided a more comfortable sitting position when stopped.

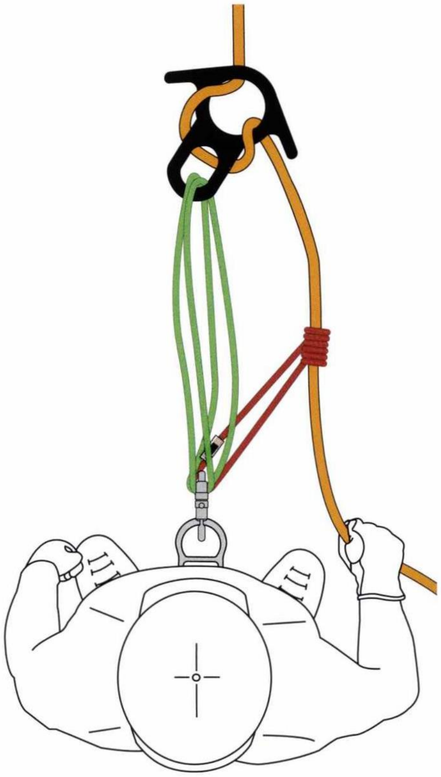


Figure 21-9: Rigging for a Tactical Rappel

Originally we used a short multi-loop strap called the CMC 8 Link to extend the descender and for a while called this the 8 link rappel system. The 8 Link allowed the length of the connection between the harness and the descender to be adjusted, keeping it as short as possible without interfering with the Prusik hitch.

We discovered that our standard length system Prusik loops were just the right length if the long one was used as the extension and the short loop was used to tie the Prusik hitch. Since a rescuer usually has two Prusik loops either on their harness or with the system equipment, the 8 Link was extra gear. It is still popular with tactical teams or the non-rescue rappeller.

Setting Up for a Tactical Rappel

The tactical rappel is usually done with a Figure 8 descender but will also work with other non-locking descenders. Start by tying a two-wrap Prusik hitch onto the rope with a short loop and connect it into your harness. Rig the Figure 8 onto the rope above the Prusik hitch. Insert a long loop through the small hole in the Figure 8. Fold this Prusik loop in half and connect both ends to your harness with a carabiner like a basket anchor. The short loop with the Prusik hitch should be on the spine side of the carabiner and the long loop to the Figure 8 on top (see Figure 21-9).

Before nearing the edge, lean back to load the system. Make sure that the Prusik hitch will hold and that there is space between it and the Figure 8. If the Figure 8 contacts the Prusik hitch, it can push the hitch down the rope, preventing you from stopping. If the start of the rappel requires a climb over a parapet or edge, make sure that the descender is positioned to clear the edge.

Using the Tactical Rappel

Control the rappel as you normally would, braking with the brake hand. The brake hand also tends the Prusik hitch. As the rope slides through the hand, it also slides the Prusik hitch down the rope. Keep the brake hand just a couple of inches below the Figure 8. This will keep the stopping distance short if you let go. When starting the rappel over an edge, pay attention to the system since the descender will be further away from you than it usually is.

Stopping is as easy as releasing your grip on the rope and the Prusik hitch. Just let the brake hand move toward the descender with the Prusik hitch inside it. As the Prusik hitch extends and tightens, you stop. There is no need to lock off the descender as the Prusik holds the rope. For a backup, pull up some of the rope from below, tie a Figure 8 loop and clip it to the harness (tying off short).

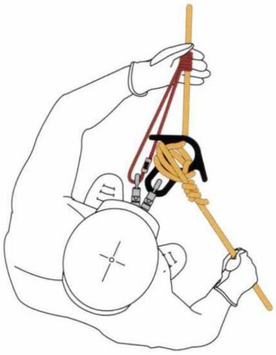
To continue the descent, reach up and grab the Prusik hitch and pull it down. Move the brake hand back to its original brake position. The Prusik hitch is easy to release since it does not support the rescuer's full weight. Its location below the descender allows the hitch to share weight with the descender.

Limitations

As with all good things, there are some limitations. The main limitation is the inability to use the body for additional friction. Traditionally, rappel instructors have taught students to wrap the rope further around the side of the hip for more friction to help control the descent.

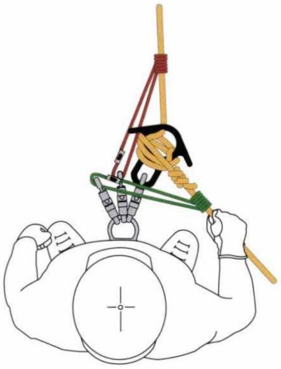
If extra friction is needed, the tail of the rope can be wrapped around and held with the free hand. Both hands brake this way while the initial brake hand still controls the Prusik hitch. Another method is to reach the free hand across in front and use both hands side by side to brake.

The second limitation arises when the rescuer is inverted, a technique used by tactical officers for peeking into windows. When the feet are wrapped around the rope for balance, it becomes possible for the officer's pants to be pulled into the descender by the rope. Make sure pants are tightly tucked into boots and the descender stays clear of clothing. This is where the length of the link is important. If the descender is directly in front of the face when starting, there should not be a problem.



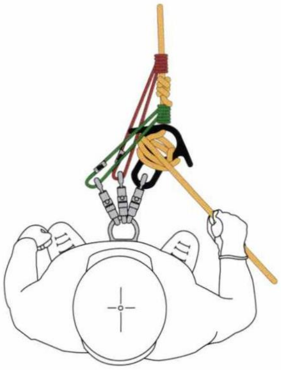
Step 1

Stop with the Figure 8 about 10 inches above the knot and set the Prusik hitch.



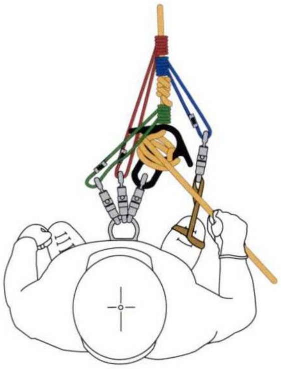
Step 2

Lock off the Figure 8 and place a second Prusik hitch below the knot.



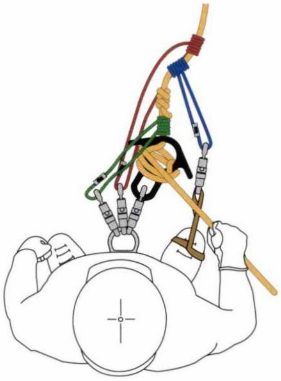
Step 3

Remove the Figure 8 and rig it below both the knot and the second Prusik hitch. Be sure to lock off the Figure 8. Now reach up and grasp the first Prusik hitch and pull down. The hitch should slide down the rope transferring your weight to the Figure 8.



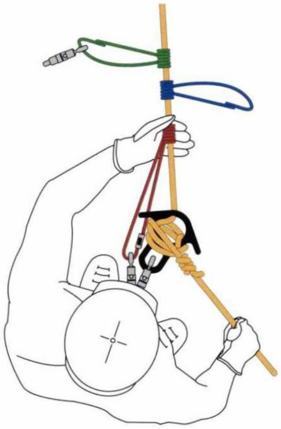
Step 4

If the first Prusik hitch does not slide, then attach another Prusik hitch (or other rope grab) to the rope above the knot. Connect a foot loop to this newest Prusik hitch.



Step 5

Stand up in the foot loop to unweight the first Prusik hitch. Slide the hitch down so that it will not be loaded when you step back down.



Step 6

Remove the first Prusik hitch and the Prusik hitch attached to the foot loop. Unlock the Figure 8 and continue the rappel.

Figure 21-10: Knot Pass on Rappel

KNOT PASS ON RAPPEL

Sometimes more than one length of rope is needed to reach the ground. The knots connecting these ropes will probably stop any descender on the market. The steps in Figure 21-10 are shown using a Figure 8 descender but also work with a Brake Bar Rack. Start the rappel using a Prusik hitch self-belay. You will also need two additional Prusik loops, a foot loop (or etrier) and a carabiner. A two-wrap Prusik hitch provides a little more room and many users find it easier to release. Others need a three-wrap to support their weight and are able to slide a three-wrap Prusik hitch when needed.

Rappels that are too long for your rappel rope will probably be too long for your belay rope also. If you are using a safety line for an independent belay, a second Prusik hitch or belay device is attached below the knot and the upper hitch or device removed.

For the procedure for passing a knot through a belay system, see Chapter 19.

RAPPELLING WITH THE CLUTCH

For rappels, the CLUTCH works by pulling down on the Control Handle with the left hand while gripping the rope with the right hand. The rope should feed behind the becket, down the side of the CLUTCH.

Pulling down on the handle will increase the rate of descent – pull too far and the panic brake stops the descent. Reset by moving the handle back to the Stand By position. To stop and work, rotate the handle clockwise to the Stand By or Stop position.

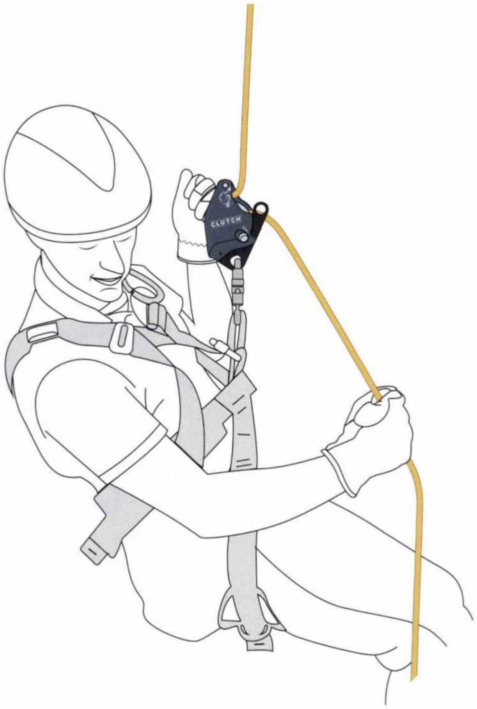


Figure 21-11: Rappelling with the CLUTCH

TIPS ON USING THE FIGURE 8 DESCENDER

Users trained on other types of descenders often do not realize the range of friction of the 8 descender. Basic friction variation depends on the angle of the rope between the Figure 8 and the brake hand and the amount of rope contacting your body. Wrapping the rope under the buttocks adds additional braking force. Minimum braking force occurs when the rope in the brake hand is held straight up above the Figure 8. As stated in an earlier chapter, we strongly recommend the Figure 8 with ears for rescue because it is easier to lock off.

Rigging the Figure 8 Descender

If your right hand will be the brake hand, stand with the rope on your right side when facing the anchor (see Figure 21-12). Hold the Figure 8 in your left hand with the large hole away from you. Make a bight in the rope with your right hand and push the bight up through the large hole from the bottom. Now put the bight over the small end of the Figure 8 and pull the rope tight. Clip the small hole of the Figure 8 into the carabiner on your harness. Take the slack out of the rope by pulling it through the Figure 8. Squeeze the carabiner gate to verify that it is locked.

The rope will run out of the right side of the Figure 8. Brake with your right hand on your right side. Left-handers start with the rope on their left side. However, all rescuers should be able to rappel with either hand as a brake hand.

For rescue or other rappels where you may stop before reaching the bottom, we prefer to hold the rope on the same side that it exits from the Figure 8, rather than wrapping it around the body. This gives a lot of freedom of movement for adjusting the friction and makes it easier to lock off the Figure 8. Holding the rope against the hip will increase the friction, but watch out for the rope rubbing against the harness. This could be a problem on a long rappel if there is a nylon strap on the harness side. We have not heard of any accidents to date, nor have we seen any substantial wear problems, but it is still something to consider.

To decrease the speed of the descent, do any combination of the following: hold the rope tighter with your hand, push the rope tighter against the body, wrap the rope around more body surface or add a carabiner as shown in Figure 21-13. What works best depends on the need for comfort and the descent rate. We strongly recommend the use of rescue rappel gloves, particularly when using kernmantle rescue ropes. The extra layers of leather help protect the hand from the friction-generated heat.

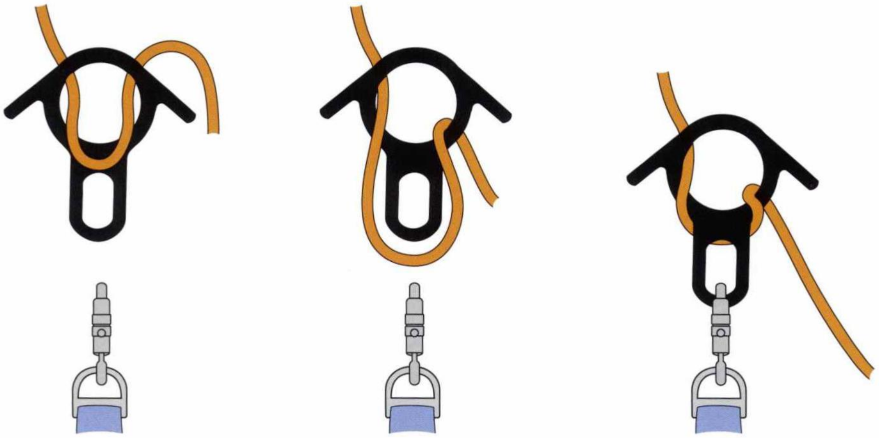
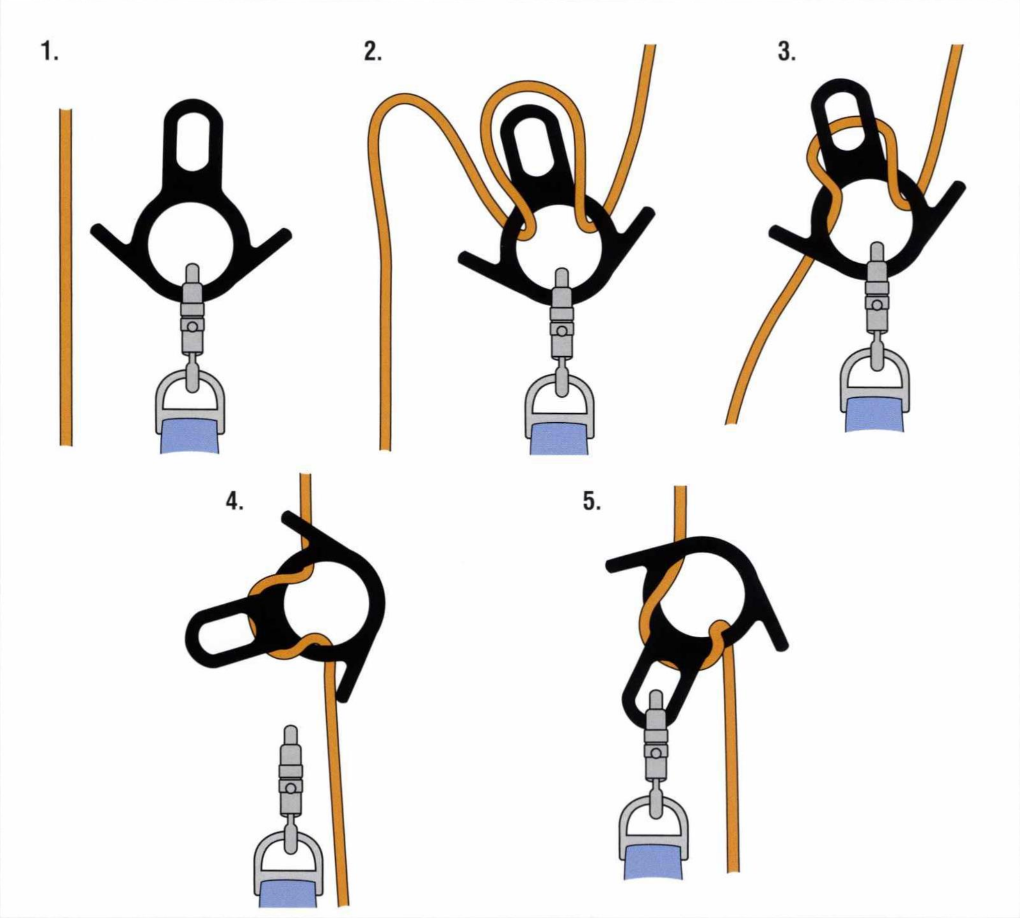


Figure 21-12: Rigging the Figure 8 Descender

CMC PRO TIP

One of the criticisms of the Figure 8 descender is the possibility of dropping it when it is disconnected for rigging as compared to the Brake Bar Rack, which remains attached to the harness. The following technique was shown to us by former Los Padres Search and Rescue Team member Tom Easop. Start with the rope to your left and your Figure 8 clipped into your harness carabiner through the large hole. Rig the Figure 8 in the usual manner by pushing a bight of rope through the large hole and then over the end. Next, unclip the Figure 8 from your harness and clip it back in using the small hole. During the time that the Figure 8 is not clipped into a carabiner, it is attached to the rope.



Stopping and Locking Off

The Figure 8 device can be locked off very securely, allowing the rappeller to stop wherever they need. The trick to locking off is to use a dynamic movement rather than stopping and then trying to hold your weight while working with the rope and Figure 8 (see Figure 21-14).

Begin the movement a short distance above the stopping point. If using a self-belay, pull the Prusik hitch down close to the Figure 8 to keep it from catching and being loaded. With the non-brake hand, grasp the bottom of the Figure 8 and the top of the carabiner attached to it. This keeps the Figure 8 from twisting and makes the lock off move easier.

Do not let your fingers get caught between the Figure 8 and the rope. Holding the junction of the Figure 8 and the carabiner helps keep your fingertips away from the rope.

Hold the rope tightly in your brake hand and let the hand move toward the Figure 8. When the hand is about 8 in (203 mm) away, smoothly draw the rope over the top of the Figure 8 and wedge it down between the Figure 8 and the standing line.

One wrap will support the weight of most people and a second wrap will secure it. To work at that location for some time, double the running end of the rope, run the bight through the large hole in the Figure 8 and then fold the loop over the top (see Figure 21-14). Pull the rope to tighten slightly.

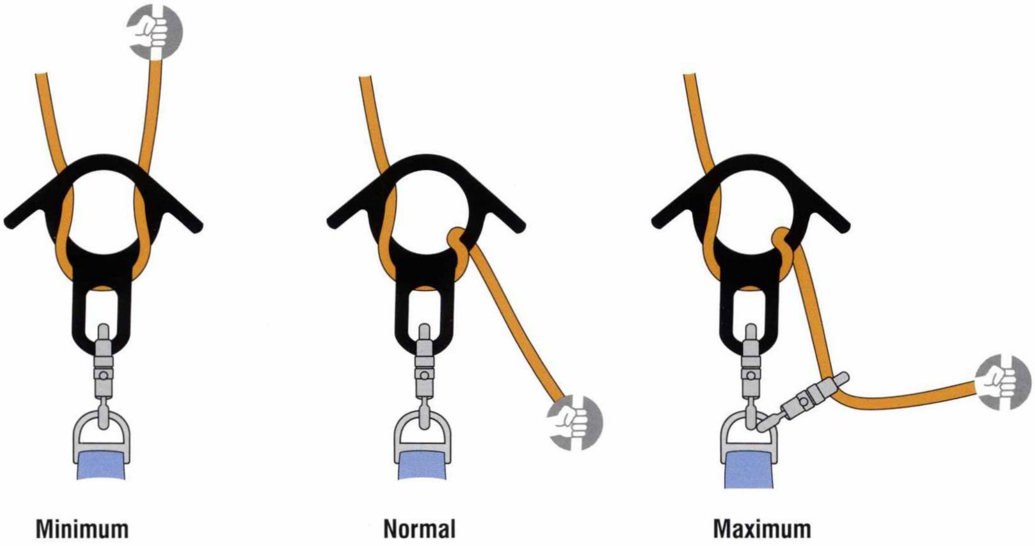


Figure 21-13: Adjusting the Friction of the Figure 8 Descender

Unlocking the Figure 8

Unlocking can be done smoothly and without any drop that can shock load the system. With the non-brake hand, grab the rope above the Figure 8 and pull down to take some of the body weight off the descender. This will make it easier to pull the wraps out from between the rope and the descender. It will also control the transfer of weight to the unlocked position.

To release the last wrap, place the rope so that it can be pulled out in a smooth motion with the brake hand and end up in the right position to continue the rappel. Un-weight the Figure 8 slightly with the non-brake hand and pull with the brake hand to free the rope.

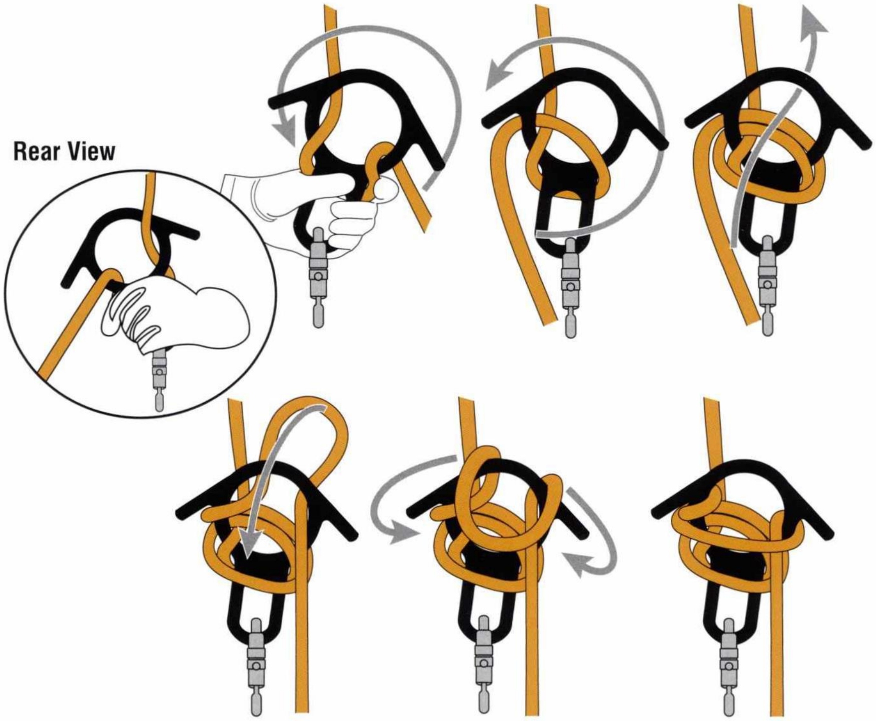
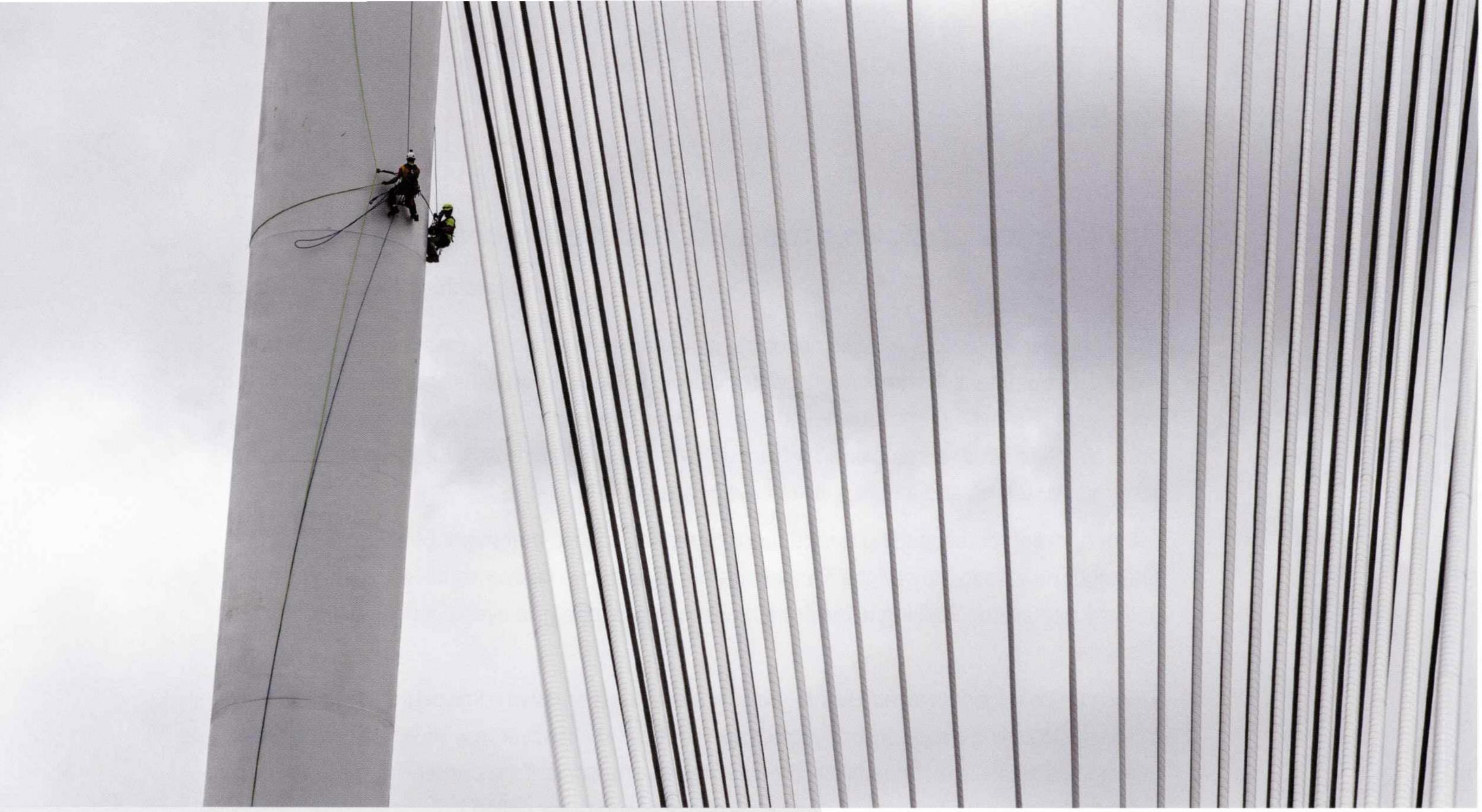


Figure 21-14: Tying Off a Figure 8 Descender

Notes



PART
05
Individual Skills

CHAPTER
22
Ascending

LEGEND: Anchor Grip Load

TERMINAL LEARNING OBJECTIVE

The student will demonstrate how to ascend a rope using mechanical devices and passing a knot.

ENABLING LEARNING OBJECTIVES

1. Describe the three primary methods of ascending a rope and their advantages and disadvantages
2. Demonstrate ascending a rope and passing a knot

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.3.9

"Any time you go down a rope, be prepared to come back up it."

—Appalachian Mountain Rescue

In this chapter we will cover basic ascending techniques that use the most common rescue response equipment. The rescuer on a litter during a vertical rescue uses ascending techniques to move up and down on the tender line. The more sophisticated ascending techniques are either a basic or an advanced technical skill for most wilderness rescue and public safety teams and a core skill for cave rescue.

Before deciding on ascending a rope, consider other options that might be faster and safer. You might be able to stay off the rope altogether by taking an easier route, such as a trail, stairway or elevator. Walking is faster than ascending a rope and even a longer route may take less time.

A rope can be rigged as a hand line to assist in climbing up or down a low angle slope. A self-belay can be added using a rope grab to protect against a fall. The rescuer may be able to climb a rock face or the side of a structure while someone belays from above. If the climb is beyond their capabilities, then ascending the rope may be the safer and faster option.

As mentioned before, one safety rule for working on a single rope is to always maintain two points of attachment from your harness to the rope at all times. Foot loops do not count, only connections from the harness to the rope. If not belayed by a second line, the rescuer will be relying completely on a single rope and must stay attached to it. With two points of attachment, one point can fail and the second will support their weight. Remember that extra Prusik we said we always carried? In a pinch, it will allow the third point of attachment, so that one of the other two can be removed for adjustment, repair or when you transfer to another rope system.

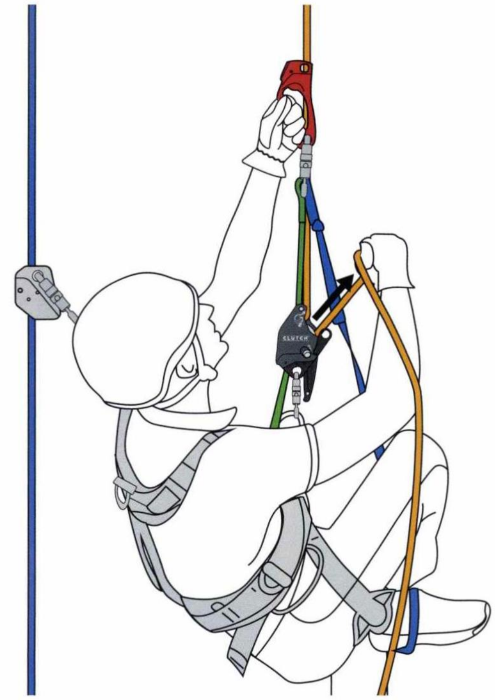


Figure 22-1: Ascending with an Independent Safety Line

USING THE CLUTCH FOR ASCENDING

Attach the CLUTCH directly to the harness. Add a rope grab with a foot loop above the CLUTCH. For a second point of connection to the rope, connect the rope grab to your harness leaving enough slack to extend the rope grab up for each step.

Place the handle of the CLUTCH in the Stand By position. Stand up in the foot loop (a handled ascender makes this easier). Pull the rope exiting the CLUTCH as you stand up, keeping slack out of the rope.

CMC PRO TIP

The CMC School and the International Technical Rescue Association both recommend an independent belay when teaching ascending skills. See Chapter 34 for using a Safety Line for a self-belay while ascending.

THE TENDER SYSTEM

In Chapter 26 we will discuss the tender setup for a vertical litter. Since the tender can move up and down on the tender line, they are already equipped to climb a fixed line. The tender system is not the most efficient system, so it is not the best for a long climb, but it is easy to set up. It is a good system for use by an edgeman going over the side to assist the litter tender because it allows for rapid conversion from a rappel system to an ascending system.

The first point of attachment is an ascender connecting the tender's harness to the tender line. While a Prusik hitch can be used, in this particular situation, an ascender is much more efficient. A second ascender with an etrier (or foot sling) attaches above the first ascender. An etrier with a tie-in, a multi-loop strap or a sling connects the harness to the upper ascender, creating the second point of connection.

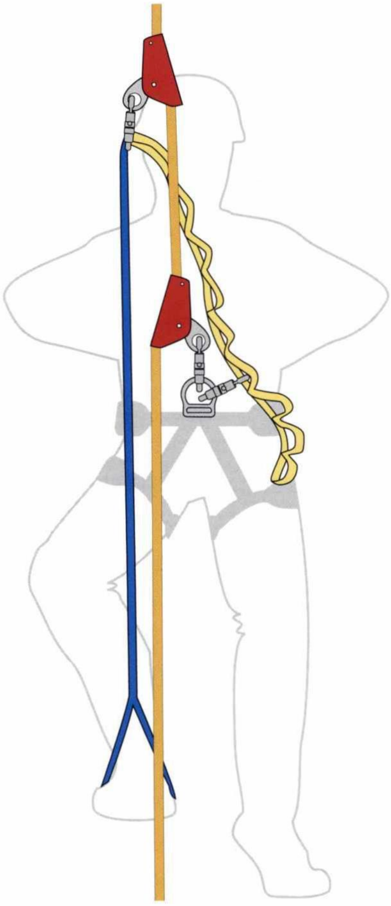


Figure 22-2: The Tender System

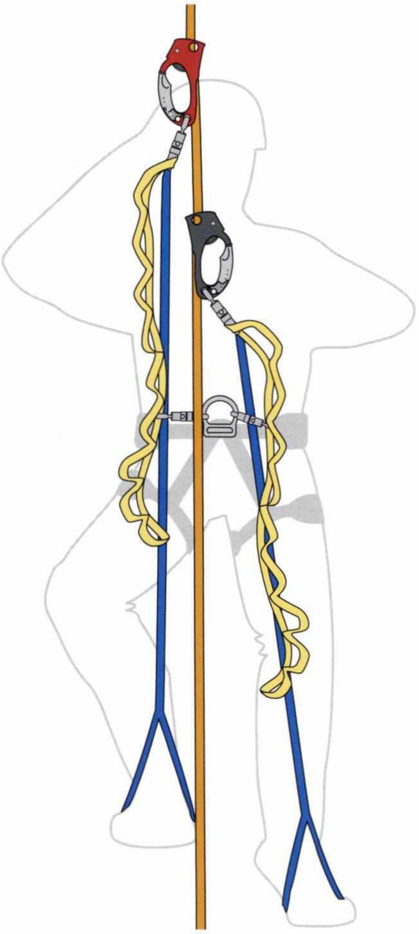


Figure 22-3: Ascending with Etriers

To operate the tender system, sit in the harness and, with your foot in the loop, slide the ascender and the etrier as high as possible, bending your leg. A little pressure on the etrier with your foot will keep it from slipping out. Then, stand up in the etrier. The ascender at the harness will slide up the rope. Pulling this ascender up tight before loading it makes for more efficient movement. This is easily done by pulling up on the rope below the ascender. Sit down to load the ascender at the harness and then bend your leg again, repeating the cycle.

Too much of a bend in the leg makes it harder to stand up. Use the size step that feels best for you. Holding the rope or the top of the etrier makes it easier to stand up and keep your balance. If one leg becomes tired, switch to the other. Two etriers connected into the upper ascender will allow both legs to work together.

ASCENDING WITH ETRIERS

This system, common with rock climbers, is more efficient, thus better suited for a longer climb than the tender system. Traditionally it was called Jumaring because Jumars were the early brand of handled ascenders used by climbers. While this technique is much easier with a handled ascender, a Gibbs cam, CMC Ascender or Prusik hitch will also work.

To set up this system, attach both ascenders to the rope. Connect an etrier or a long sling with a foot loop from each ascender to act as stirrups. They should be long enough to allow the ascenders to be about chest height when the rescuer's feet are in the loops. A girth hitch around the foot helps to keep the loops from slipping off.

If the lengths of the etriers are adjusted so that the ascenders are about a foot apart when the feet are together, efficiency will be increased by taking a full step with each leg. With practice, you will learn which spacing works best. A vertical climb is different than ascending a rope rigged at a low angle, so practice for both is necessary, and practice before having to ascend on a rescue is essential.

Connect a short web sling or multi-loop strap from each ascender to the harness. These provide the necessary two points of attachment to the rope. They also allow the rescuer to sit in the harness when stopping to rest or work.

Ascend by pushing the top ascender up while keeping a little weight on the etrier (to keep it from slipping off the foot while the leg is bent). Stand up as the bent leg is straightened, pushing the lower ascender up with your hand.

The limitation to this system is the upper body strength and effort required to hold oneself upright. A short climb is not a problem, but if climbing a longer distance, the arms will get tired. A chest harness makes it easier by taking much of the load off the arms. See Chapter 08 for tying an improvised chest harness.

TEXAS SYSTEM

The Texas system is more efficient for a longer climb since less effort is needed to support the upper body weight as the climber sits during each set of moves. Again, handled ascenders are more efficient but a cam-type ascender or a Prusik hitch will also work. While usually rigged with a single foot sling, two *etriers or a double foot loop* can be used.

Connect the upper ascender to your harness with a short sling. A 22 x $^{1}/_{2}$ in (56 x 1 cm) runner attached directly to the ascender with a girth hitch works well for a person 6 ft (1.8 m) tall. Connect an etrier or foot loop to the lower ascender. For your second point of attachment to the rope, connect this ascender to your harness with a multi-loop strap or sling, allowing enough length for the ascender to move up the rope.

Attach the ascenders to the rope, leaving enough space between them for the upward step. This will be about 12 in (30 cm) with one ascender about the height of your face; too high and the arm will tire more quickly. The lower ascender should be about mid-chest. You will have to work out what is best for you since too big a step is hard on the leg and too small a step is very inefficient.

Ascending is a series of sit-stand moves. Move the upper ascender as high as you can and then sit down into your harness. As you bend your leg, move the lower ascender up the rope. Stand up and move the upper ascender as high as you can; repeat.

FROG SYSTEM

The frog system is the basis of the ascending systems used by Rope Access Technicians. Because the chest ascender moves up the rope as the climber stands up, it takes less effort than the Texas system.

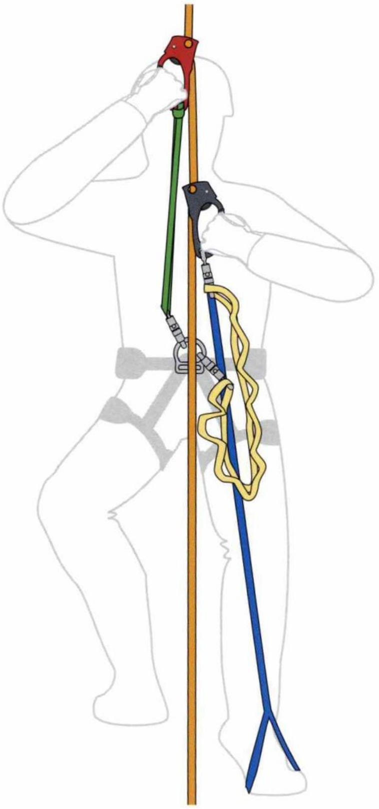


Figure 22-4: Texas System

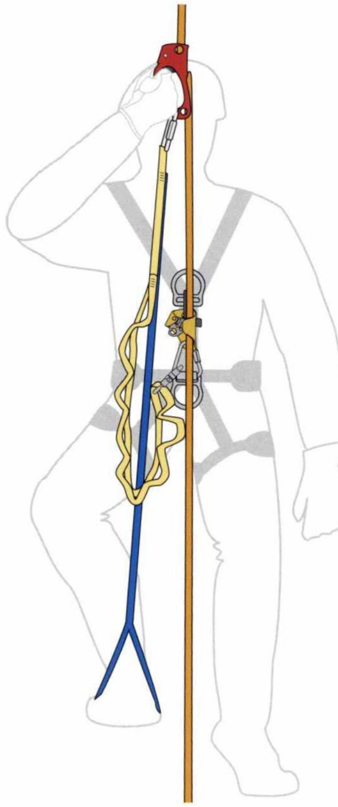


Figure 22-5: Frog System

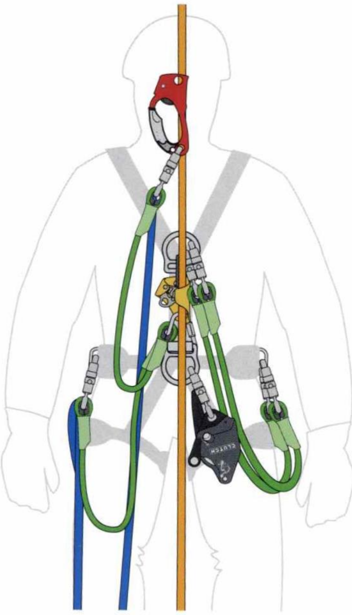


Figure 22-6: Rope Access Worker with Frog System

A full-body harness, or a sit harness and chest harness, are required for the frog system. The chest ascender connects between the front-waist D-ring and the sternal D-ring. A non-handled ascender, such as the Petzl CROLL, is usually used for the chest ascender. Connect an etrier or foot loop to a handled ascender. Also connect this second ascender to the waist D-ring of the harness for the second point of attachment.

Attach both ascenders to the rope with the handled ascender about face height. Bend your knee and move this ascender up and then stand up. The chest ascender will move up as you stand. Sit down with the chest ascender supporting your weight. Bend your knee, move the handled ascender up and stand up again. Both hands can grip the handled ascender, allowing the arms to pull to assist the standing up move. If you plan to do a lot of ascending with the frog system, Petzl and CMI make an ascender with a double handle.

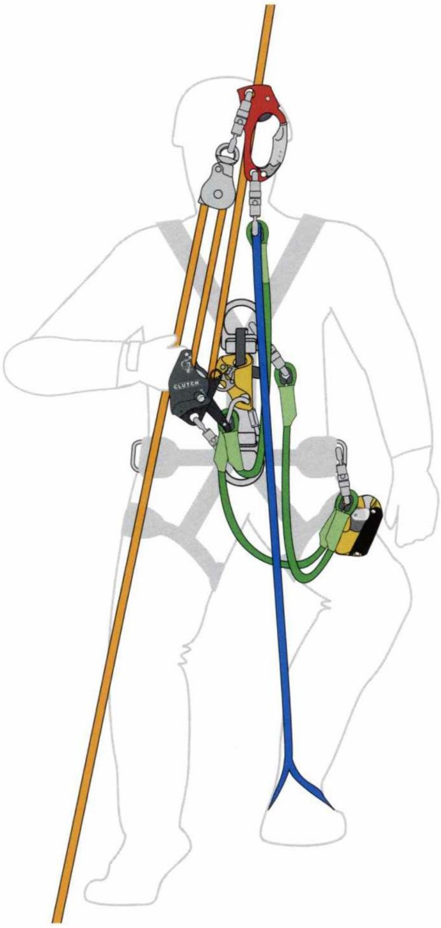


Figure 22-7: RAD System

As a standard practice, Rope Access Technicians use a second safety line when working on rope. Their back-up device connects with a lanyard to the sternal D-ring on the harness. The Rope Access Technician moves the rope grab up as they ascend and down as they descend, always keeping it above waist height. This action plus a short lanyard minimizes the impact force on the safety system should a failure occur in the working line system.

A variation on this system is to rig the top ascender below the chest ascender. This keeps tension on the rope when you stand up. When reaching down to lift the ascender with the foot loop, you may be able to slide the ascender up without pulling up the rope as well. The downside of this set up is the inability to pull on the upper ascender to help you stand up.

If your plan is to rappel as soon as you reach your high point, you can use an auto-stop descent control device in place of the chest ascender. As you stand up to ascend, the rope must be pulled through the descender, which then locks when you sit down for the next step. The advantage to this system is the quick conversion to descending; just remove the handled ascender and you are rigged for a descent. Running the rope from the descender up through a pulley on the top ascender makes ascending more efficient as you can pull down on the rope rather than up as you stand up. This is known as the RAD System for Rapid Ascent and Descent.

ROPE-WALKING SYSTEMS

The previous ascending systems use the basic gear normally found in a rescue pack and will get the job done over a short distance. For very long climbs, cavers use a rope-walking system. A good system supports the upper body and transfers the work to the legs, which greatly increases efficiency. Rope-walking systems are usually custom built as each user has their own idea of what works best. If a more advanced ascending capability is needed, talk to a vertical caver. They can help you decide on and put together the type of system that will work best.[1]

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[1] An excellent source on ascending is Padgett, Allen; Smith, Bruce. *On Rope*. 2d Edition. Huntsville, AL: National Speleological Society; 1996.

Notes

PART
05
Individual Skills

CHAPTER
23
Fall Protection

LEGEND: Anchor Grip Load

TERMINAL LEARNING OBJECTIVE

The student will recognize basic fall protection equipment and concepts.

ENABLING LEARNING OBJECTIVES

1. Describe the differences between fall protection, fall arrest and travel restraint
2. Demonstrate the proper use of a bypass lanyard for a protected climb
3. Discuss the hazards, considerations and restrictions of lead climbing

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.3.7

Rope rescue is work at height, and an edge, whether natural or structural, is almost always present. Fall protection planning, either mandated by OSHA or just by common sense, should be a consideration at every incident. Several fall protection concepts were covered when we talked about belay systems for rappels and litter systems. Training in recognition and mitigation of a fall hazard should be part of every Rope Rescue Technician's background. In this chapter, we take an overall look at the principals of fall protection planning.

MITIGATION

Fall protection does not always require a belay or safety line but rather an awareness of the hazard and then steps taken to mitigate it. It may be as simple as keeping team members away from the edge where a fall could occur. Rescuers with a recreational climbing background or industrial work-at-height experience may be comfortable working near an edge, but with the increased number of people and activity during a rescue, the chance of a rope or another person causing a loss of balance is significantly increased.

Main line and belay line anchors should be set back from the edge whenever possible to provide a safe working area as a sudden movement of the rope or a trip by a haul team member could initiate a fall. Rigging the litter or setting up a portable high directional should also be done a safe distance away from the edge.

Some teams lay flagging tape or a length of web on the ground to indicate the area near the edge that may be entered only by personnel on a belay or safety line. When a rescuer crosses the line, fall protection measures are required. All other personnel at the scene remain on the safe side of the line.

TRAVEL RESTRAINT

A ***travel restraint*** system prevents the rescuer from physically reaching a position where a fall could occur. Examples include:

- The initial rescuer or medic looking over the edge to locate the subject
- A litter tender and edge men moving the litter over the edge
- A rescuer beginning a rappel
- A rescuer positioned to observe the litter and provide communication to the system operators
- The operator when a system must be placed close to the edge
- An instructor coaching a litter or rappel exercise

To set up a travel restraint system, attach a fixed line to an anchor away from the edge. One side of the AZTEK System was designed for this purpose. The best choice is an anchor completely independent of the main line or belay line system. If the system is connected to a BFR, adding the travel restraint anchor to the BFR may be more efficient than trying to find another anchor.

Connecting the rescuer to the fixed line with a rope grab allows the length to be adjusted much more easily than trying to tie a knot at the correct position. The rescuer should be close enough to the edge to perform their assignment but prevented by the fixed line from physically going over the edge. It is usually most convenient to connect the rope grab to a tie-in point on the back of the rescuer's harness.

Use a Prusik hitch as the rope grab on a fixed line or use the AZTEK edge travel-restrict system as a travel restraint. A figure 8 loop makes a better stopper knot as it can also be attached to the back of the harness.

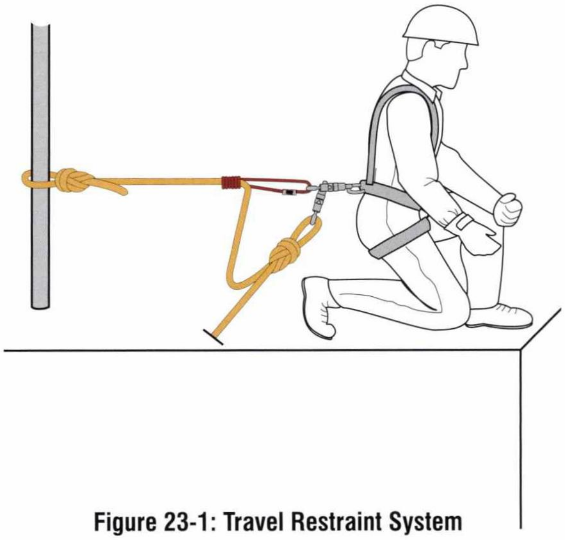


Figure 23-1: Travel Restraint System

FALL ARREST

As the name implies, a ***fall arrest*** system arrests a falling worker over a given distance. The most common system used in industry includes a full-body harness, an energy absorber and a lanyard to an anchorage. Fall arrest system design takes into account the strength of the anchor, sufficient space below the worker to allow for the lanyard and the energy absorber to extend without the worker striking any structural member and minimizing maximum arrest force.

For rescuers working at height, an engineered personal fall arrest system meeting ANSI Z359 (or any of the other fall protection standards) is seldom available. Fall protection is rigged on scene, and the fall distances must be kept at the very minimum to prevent injury.

Also, fall arrest harnesses are designed to support a fallen worker but not a working rescuer. Most have only the required dorsal D-ring. Few also have a sternal D-ring. A very few offer a D-ring at the waist to allow an attachment point necessary for rappels or the litter tender's line.

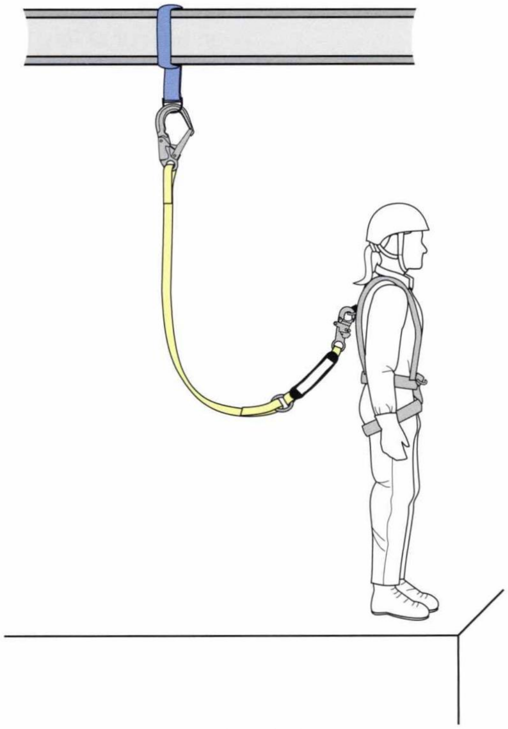


Figure 23-2: Fall Arrest System

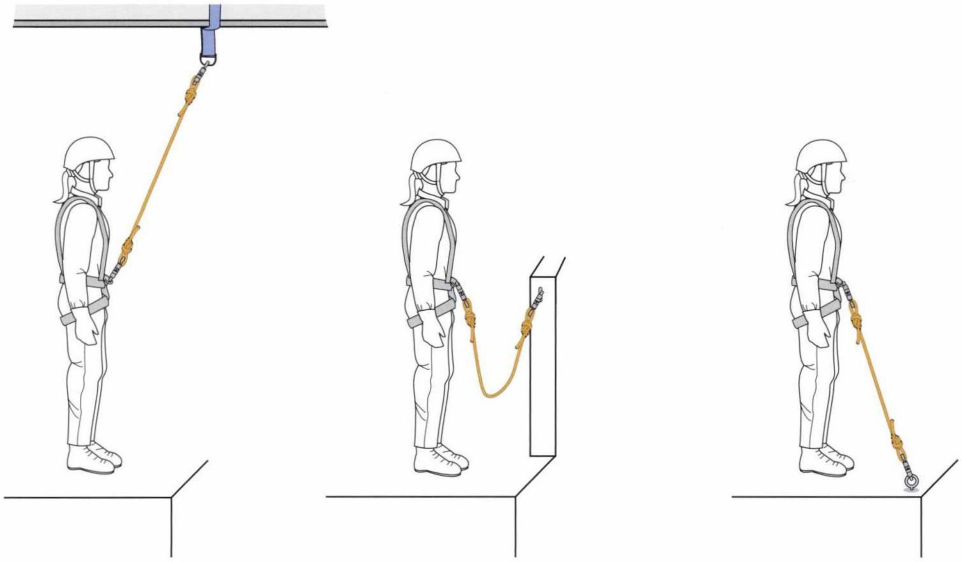
Fall arrest situations on a rescue could be any of the following. Rescuers usually think belay when rigging a fall arrest system, several of which were discussed in Chapter 15 on belay systems. In this chapter we will continue to use the term fall arrest:

- Rescuer on a lowering system for a pick-off rescue
- Rescuer conducting a rappel pick-off rescue
- Litter system on a high angle or low angle evacuation

- Rescuer or subject ascending/descending steep terrain on foot where a fall would be serious
- Rescuer or subject ascending/descending an unprotected ladder
- Rescuer on a lead climb or traverse
- A student learning rappels

Fall factor is an important consideration both in rigging and operating a fall arrest system. Fall factor is the height of the fall before the belay system activates divided by the length of the rope or lanyard between the belay device and the rescuer, or if no belay device, then the belay anchor. For example:

- **Fall Factor 0:** A rescuer with a six-foot lanyard that is connected to an anchor point above such that no slack exists. The theoretical fall height is 0 and the fall factor would be 0. In reality the fall height is greater than 0 as the lanyard will have some stretch when it takes the rescuer's load.
- **Fall Factor 1:** A rescuer with a six-foot lanyard standing next to the fall arrest anchorage. The fall height will be six feet and with a six-foot lanyard, the fall factor would be 1.
- **Fall Factor 2:** A rescuer working on an edge with a three-foot lanyard connecting to an anchor at foot level. The fall height would be twice the length of the lanyard (six feet) and the fall factor will be 2.



Fall Factor 0

Fall Factor 1

Fall Factor 2

Figure 23-3: Fall Factors

The higher the fall factor, the more serious the fall and for this reason, the design and operation of the fall arrest system should keep the anchor point above the rescuer. This is also true of a belay system operated by another rescuer. Keep the anchor point high and minimize the slack in the belay line.

For the rescuer working near an edge, a travel restraint system is the better choice since it prevents the fall in the first place. If greater mobility is required, a belay system can be set up and as long as the belayer keeps the slack out of the belay line, a fall will not occur or at least should be very minimal. When setting up either system, keep in mind the possibility of a pendulum. While the working edge may be in front of the rescuer, a fall hazard may also exist to either side.

If the rescuer is working on the edge using a lanyard connected directly to an anchor, always look for the highest possible anchor point. Connecting to an anchor near foot level will result in a high fall factor event and unless a fall arrest energy absorber is used, the anchor or lanyard could fail.

One set up we have seen that has a significant potential for disaster is a fall arrest anchor set up by rigging a length of rope or webbing along the edge of the cliff or structure. Rescuers working at the edge would attach into this line with a short lanyard. Since the line usually ends up at foot level, a high fall factor fall would result and the resulting force transmitted to the anchors at either end would have the same force multiplier that occurs in a high line. If more than one rescuer is using this anchor, they may also be pulled off balance further increasing the forces. If the line was set up using one-inch tubular webbing or if the anchors at each end are not sufficiently strong, a failure of the system is most likely to occur.

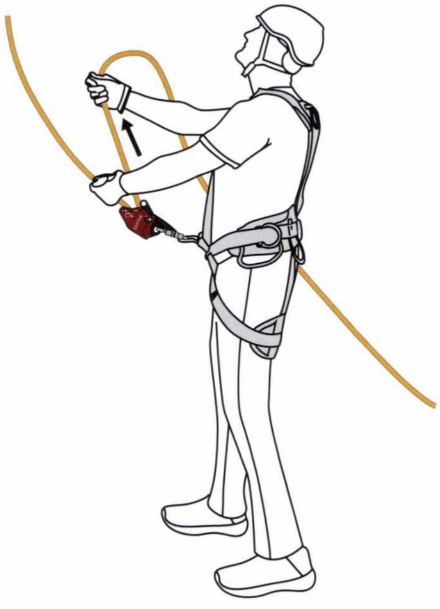


Figure 23-4: Belaying a Lead Climber with the CLUTCH

LEAD CLIMBING

The belaying of a lead climber is a fall arrest system that rescuers would use when accessing a tower or climbing an unprotected ladder on a structure. While most wilderness rescue teams can find a route to a location above the subject, sometimes that is not an option and the team members must climb up from below. Rescue teams that may have to access the subject from below will train in the lead climbing techniques likely to be used. These may be rock climbing skills, tower and structure climbing techniques or both.

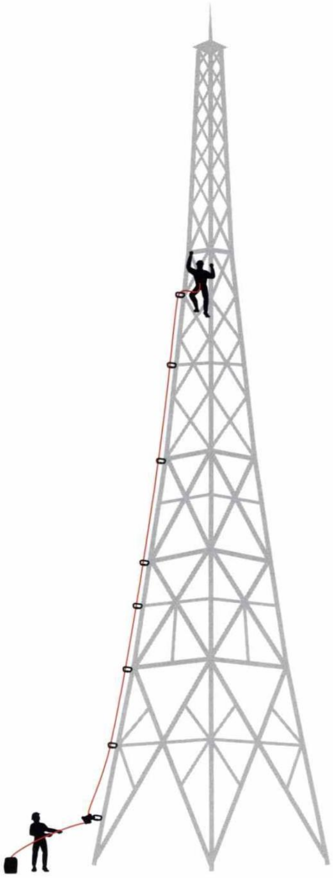


Figure 23-5: Lead Climbing

ATC Type Device

CMC FastLink Anchor Strap

Petzl GriGri

CLUTCH

Since lead climbing is a high fall factor activity, energy absorption is required to minimize the force on the climber, the belayer and the belay system during a fall. For this reason, a dynamic or high-stretch rope is used. The climber will also place intermediate points of protection during the ascent. The rope runs through a carabiner at each point and the height of the fall is determined by how high the climber is above the last point of protection. As the climber ascends, the length of the rope increases but the height of the fall is limited to how high the climber moves before placing another anchor point.

Ascending a rockface requires placing artificial anchors into cracks in the rock or expansion bolts drilled into the rock. This is a rock climber's skill and outside the scope of this text. If your team needs this capability, it will need to either recruit rock climbers or learn from a qualified instructor.

On a tower or structure, webbing or rope slings wrapped around a structural member can be used for protection anchors. Specialized anchor slings, such as the CMC Azzard or FastLink have cut-resistant webbing and are designed to be easily wrapped around a structural member and connected with one hand while the other hand holds on to the structure.

Belay devices for rescue lead climbing originally came from recreational climbing. An early device was the Black Diamond ATC (Air Traffic Controller) and today there are multiple variations of the tube shaped devices. What the all have in common is the requirement for the belayer to pull down, increasing the friction in the device to hold the climber's fall.

Auto-locking devices such as the Petzl GriGri® and others from recreational climbing do not require a response from the belayer to catch the fall. The CLUTCH meets the EN requirements for belaying a lead climber. It operates similarly to other auto-lock belay devices.

For all of the belay devices, be sure to maintain the grip on the rope with the brake hand. Position the other had above the belay device to assist the brake hand when taking up slack. Each of the belay devices will allow the belayer to lower the climber to the ground.

There is an ongoing discussion whether a static or low-stretch rope could be used to protect a lead climber under certain circumstances. The theory is that as more rope is deployed during the climber's ascent, the fall factor decreases and the severity of the impact force also decreases. If the climber is careful to keep protection points closer and whenever possible not to climb above each point of protection, the fall factor is also minimized. Additional energy absorption can be added by placing an energy absorber between the climber's harness and the rope or between the belay device and the belay anchor. A low-stretch rope also helps protect the falling climber by stopping the fall with less of a drop.

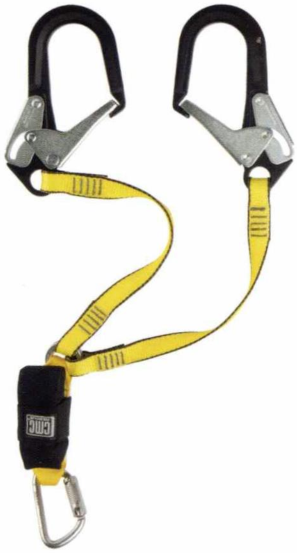


Figure 23-6: Bypass Lanyard

Belaying a Lead Climber with the CLUTCH

The CLUTCH meets the EN requirements for belaying a lead climber. It operates similar to other auto-lock belay devices. Maintain grip on the rope with the brake hand. Position the other hand above the CLUTCH to assist the brake hand when taking up slack.

CLIMBING WITH A BYPASS LANYARD

A bypass or Y-lanyard allows one fall arrest lanyard to be disconnected and moved while the second lanyard remains connected to provide the necessary fall protection. By attaching the connector to a higher rung on a ladder or structural piece on a tower, the climber can move up several steps, then move the lower lanyard to the next rung an arm's reach up.

Fall arrest Y-lanyards usually are the same length and have the same built-in energy absorber as a single fall arrest lanyard. A variation of this design has a shorter center lanyard that allows a worker to clip into an anchorage and sit in their harness without loading the energy absorber in the longer lanyards.

A bypass lanyard is designed for climbing and the length of each lanyard is equal to the reach of the arm. For safety, each connection should never be below waist height in order to maintain a low fall factor.

Notes

PART
06
Rescue Techniques

CHAPTER
24
Access & Stabilization

TERMINAL LEARNING OBJECTIVE

The student will demonstrate how to stabilize a patient before they are ready to be packaged for extrication.

ENABLING LEARNING OBJECTIVES

1. Discuss the need for both physical and emotional stabilization
2. Demonstrate the proper technique for putting a Lifesaver Victim Harness on a patient

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.2.20 | 5.3.3 | 5.3.8

LEGEND: Anchor Grip Load

The first step in a rescue is to access the subject. The second step is to then stabilize their condition to prevent further injury. Stabilization can be physical, medical or emotional. Two examples of exposure to physical injury are falling or being hit by rock or debris falling from above. Medical exposure could be a deteriorating condition from the effects of shock or hypothermia. Emotional exposure could be a very scared or suicidal subject.

Until the subject is reached, the exact rescue problem cannot be fully evaluated. Too often the reporting party's evaluation, a long-distance observation and even the subject's own statements turn out to be not quite accurate. The medical condition of the subject, their ability to assist rescuers and the difficulty of the terrain will determine the type of evacuation.

GAINING ACCESS

How access is gained to the subject depends not only on the terrain, but also on the rescue team's equipment and skills. Generally it is easier to lower a rescuer or to rappel down to the subject than to try to climb up from below. A lower or rappel requires rescuers to reach a point above the subject where they can securely place anchors. Climbing up from the bottom requires a rescuer with lead climbing skills, climbing rope and equipment and then the necessity of placing anchor points at or above the subject to set up systems. Anchor points are generally, but not always, easier to find at the top of a cliff or building than in the middle of a cliff or at the subject's location. Other directions of access could be a traverse from the side or a pendulum across.

It takes the experience of performing rescues and a familiarity with local terrain to develop the judgment needed to evaluate the situation and quickly select a safe route of access whether from below, above or across. Varied training scenarios also help develop the experience needed to analyze a situation.

Make voice contact with the subject quickly. While this may be essential just to locate the subject, it also allows rescuers to start evaluating the subject's condition. If possible, assign a team member to talk to the subject while the team readies the system and gathers gear. Ask the subject to remain still and get them involved in the rescue by asking questions about their situation.

Even as the rescuer approaches the subject, talk to them and tell them what you are going to be doing. Calm them down. Remind them not to move. If there is something they can do to help themselves or you, ask them to try it. Make sure they understand exactly what you want done. It is better to have them do nothing at all than to make their situation worse.

Here are some lessons we have learned about approaching a subject:

- Rule number one: protect the rescuer, protect the subject
- Pick a path that is as free as possible from rocks or other debris, which might fall and hit the subject or a rescuer

- Keep any rappel line away from the subject. It may hit them when deployed or they may try to grab it. If they grab for the rope and miss, they may fall. If they grab the rope and pull, they can stop the rappel just like a bottom belay. A rope bag allows the rope to be kept with the rescuer during the descent. Once the subject is reached, the bag can be thrown. Lowering the rescuer avoids this potential problem and frees the rescuer's hands
- Have the gear to secure the subject ready for immediate use. The subject may move toward or jump for the rescuer, which is another good reason to have the hands free. Stay out of their reach until ready to put them in a harness and on belay

PHYSICAL STABILIZATION

When the subject is reached and there is a risk of a fall, put them in a harness or check the one they are wearing to make sure it is adequate. The harness placed on the subject should already be connected to the system. If the subject's harness is used, connect it to the system as soon as it can be reached. This connection to the system can be done in several ways.

1. If the plan is a pick-off using a lowering system, connect a Pick-Off Strap to two Prusik hitches, one on the main line and one on the belay line.
2. If the plan is a pick-off on rappel, use a Pick-Off Strap or a load tender to attach the subject to the rescuer's descender.
3. If you do not want the subject attached to your system, a separate belay can be used. This works well for a subject that is able to climb up or move down on their own.

Each of these options assumes that the rescuer is staying on the system. If the subject is at risk for a fall, the rescuer is probably equally at risk.

Try to avoid connecting the subject to your harness. Having their weight added to your harness greatly reduces your mobility. Also, you may need to leave the subject on the system while you move about to complete the rescue.

Anchors placed on a lead climb from the bottom or during a traverse may not be as secure as desired. If possible, try to place a separate anchor for the subject and rescuer.

Placing a helmet on the subject and keeping them close to the wall protects them from falling objects. In some cases the subject may have to be moved to a safer location or covered with a pack. Team members working above the subject should always be aware of the danger of dropping equipment or knocking down rocks or debris.

Putting a Harness on the Subject

If the subject is not wearing a harness, they will need one placed on them in order to be connected to the system. The quickest attachment is a piece of web wrapped around the waist. A multi-loop strap allows quick size adjustment. This will hold the subject, but this minimal support may injure the subject if they fall. Proper care requires placing the subject into a harness. With the right equipment and practice, a harness can be put on the subject just as fast as a sling around the waist.

For a person clinging to the side of a cliff, it may be difficult to put on a climbing or rescue harness without risking a fall. Any harness that requires the subject to lift a leg to put their foot through a leg loop risks a loss of balance. A person sitting may not be able to reach their feet, or the ability to bend a leg may be prevented by an injury. The wrong size harness could be uncomfortable or risk having the subject fall out of it.

Lifesaver Victim Harness™. Rick Homan of the Montrose Search and Rescue Team (a Mountain Rescue Association team with the Los Angeles County Sheriff's Department) helped develop the CMC Lifesaver Victim Harness. The Lifesaver Harness attaches to the subject quickly, can be put on without any subject movement, fits small children to large adults and is as foolproof to operate as possible. Color-coded web helps make sure the right snap goes to the correct V-ring (see page 257).

Chest Harness. Always take along a chest harness or be able to improvise one. If the subject is unconscious or for any reason unable to keep their position upright, a chest harness will support their upper body. If you do not have a commercial chest harness, an adequate one can be improvised from one-inch web as shown in Chapter 08. Chest Harness for the Livesaver Victim Harness was designed for lifting a patient from a confined space. It was not intended as a chest harness for rope rescue operations because it does not have shoulder straps to keep it in the proper position.

A chest harness can be put on a conscious subject but not clipped in to the rope until needed. Then, if the subject needs help supporting their upper body, the harness is there, ready to go. If there is exposure to falling objects, it may be a good idea to clip the chest harness into the rope anyway.

MEDICAL STABILIZATION

Begin by establishing communication with the subject. While approaching, talk to them and calm them down. Let them know who you are and what will be happening. This is basic medical procedure in any emergency.

The subject may be able to do something to help themselves or to help the rescuers during the time it takes to reach them. If they can answer questions, gather information about the accident and their medical condition. If there is a risk of a fall, secure the patient to a safety line and then begin your assessment and treatment. Additional medical gear or personnel can be brought down as needed to treat their injuries and to prepare them for the evacuation.

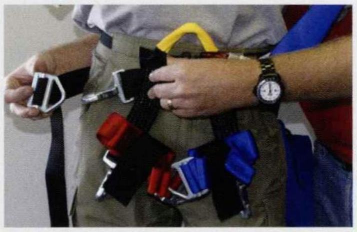
An often discussed question is: How much treatment to apply at the scene as opposed to making a quicker evacuation and starting treatment on safer terrain? Treatment for a subject hanging on a rope is very limited. Airway management and CPR are most likely impossible and cervical precautions are very primitive. Moving the subject to a working surface is usually essential before any significant treatment can be done.

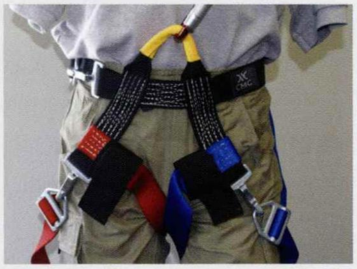
A subject in a litter can receive only the most basic life support. While effective airway management can be done, the CPR decision will be dependent on the length of time it will take to transfer the subject to advanced life support care.

Using the Lifesaver Victim Harness™

The following steps for putting on the Lifesaver Victim Harness can be used for the most common situations. Practice and experience will allow you to modify the steps for unusual situations.

1. Pull the attachment loop (yellow) out of the top of the bag and connect it to a Pick-Off Strap or the subject's belay line. Tighten the drawstring so that the harness does not fall out of the bag. Descend to a position 5 ft (1.5 m) above the subject. Talk to the subject, telling them what you are going to do, what they should do and what they should not do. While talking, open the top of the bag and prepare the harness to be put on the subject.
2. Descend to a position that is slightly above and to the left of your subject (for the right-handed rescuer.)
3. Hold the waist snap in your left hand with the snap's gate out away from the subject. The attachment loop (yellow) should be next to your wrist. The leg loops should be below the waist strap and on the side away from the subject.
4. Starting with the waist strap too short, hold the waist V-ring in your right hand. Reach around the subject's waist, while extending the strap and clip the V-ring into the waist snap. Pull the waist strap tight, keeping the attachment loop in the center of the subject's front and the strap high on the subject's waist. The harness can be reversed if the rescuer is on the other side of the subject.
5. Pull a leg loop down to release it from the retaining straps. Pass it between the subject's legs and around to the side. Snap the V-ring into the matching color snap. Then connect the other leg loop. Pull the straps until the leg loops fit the subject snugly.
6. Check for the following:
   - The V-rings are securely clipped into each snap.
   - The harness is snug and not pinching or binding.
   - The snaps are not causing the subject any discomfort.
   - The subject's carabiner is locked.
   - There is no slack in the system.





Even with the stability of a litter, it may be better to move the litter and rescuer to a stable position before splinting fractures. Trying to do this in an unstable situation may be more harmful than the transport up or down. Basic life support that can be done at the scene is the first priority. For serious injuries, the sooner the subject can be packaged and safely transported to a mobile intensive care unit and the emergency room the better.

If there is a need to do any treatment while hanging on a rope, practice it. This will help develop skills, weed out any problems and make you very aware of what is and is not possible.

EMOTIONAL STABILIZATION

A frightened or nervous subject is a danger to the rescuer and to themselves. Talking to the subject is the best way to calm them down. To distract the subject, give them something to do such as suggesting a better hand hold. Do not suggest anything that may cause them to move and lose their balance if the position is precarious.

If it is apparent that the person may fall or jump, the rescuer is better off being lowered than rappelling. That way both hands will be free to catch the subject. Even if you cannot get a harness and belay onto the subject, you can support their weight as your team members lower both of you.

Suicidal Subject – We have been asked for suggestions on how to belay a rescuer when approaching a suicidal subject. As with other systems, the primary concern is protecting the rescuer. Always work in a team with a rescuer and a belayer. The safest way is to rappel or be lowered from above to the subject's position. Lowering requires an extra team member but leaves the rescuer's hands free.

Consider using a mechanical advantage system to lower the rescuer. This provides the option of pulling the rescuer back up out of the subject's reach if safety requires. It also provides the option of raising or lowering the rescuer and subject if contact has been made.

If going out on a ledge, have the belayer set up as close as possible to minimize any pendulum movement if the rescuer falls. Putting intermediate anchors along the way will also reduce the distance of a fall. A traverse like this is a climbing or rope access technique and is best done by an experienced climber. Do not go out until the belayer has set an anchor and is ready to belay.

Either way, if the subject jumps or falls on the rescuer and they end up hanging on the rope, they will then need to be rescued. In preparation for this, the necessary equipment and people should already be on scene and set up. While waiting, the rescuer should try to attach the subject to the rescuer's line to take the weight off of their arms. A well-prepared rescuer takes an extra Prusik, a harness for the subject, and spare carabiners. The rescuer will also learn the advantage of a comfortable harness.

PART 06

Rescue Techniques

CHAPTER 25

Stranded Person Pick-Off

TERMINAL LEARNING OBJECTIVE

The student will demonstrate a lowering pick-off rescue.

ENABLING LEARNING OBJECTIVES

1. Describe the advantages and disadvantages of different types of pick-off rescues
2. Demonstrate how to set up a team based pick-off rescue
3. Demonstrate how to set up a rappel based pick-off rescue

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.3.1 | 5.3.2 | 5.3.3

LEGEND: Anchor Grip Load

A full litter evacuation that includes patient packaging and setting up systems takes time. If the subject is not injured, but just stuck, or if the type of injury permits, a litter may not be needed at all. In cases where the subject is experienced, often the case with rock climbers and cavers, they can assist with the evacuation and will be able to help protect their injuries. For example, a climber with an injured hand may be able to rappel or ascend with assistance from a rescuer rather than waiting for a litter to be set up.

Sometimes an immediate evacuation is required despite the subject's condition. The subject may need immediate treatment that cannot be performed on the rope, or the subject and the rescuer may be exposed to additional harm. An example of the first is a heart attack suffered while ascending a rope. An example of the second is a SWAT team member injured or stuck on a rappel while exposed to hostile fire. The choices are one of sure death on the rope versus a chance of survival if the bottom can be reached quickly through an aggressive rescue procedure.

THE PICK-OFF RESCUE

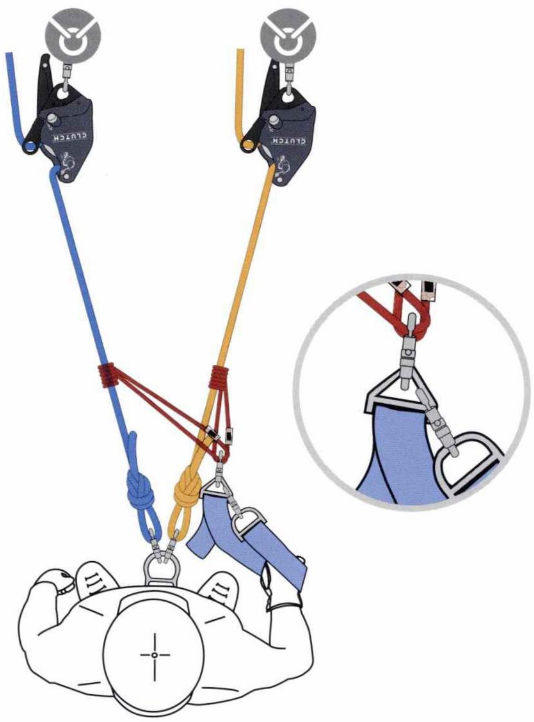
A pick-off rescue can be used for both a vertical or a low angle evacuation. The subject should be uninjured or have only minor injuries that can be easily protected.

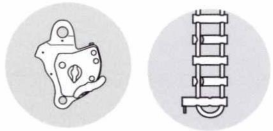
The traditional pick-off technique was performed by a single rescuer on rappel. It was used in situations where personnel were limited and a full litter evacuation was not essential or there were time limitations. Today many teams prefer the lowering pick-off because of the higher level of safety, and in a team-based response sufficient personnel are on scene. In fact, with an experienced team, a lowering pick-off will be faster since the rescuer has both hands free to work with the patient the moment contact is made. With sufficient personnel available, the lowering pick-off can then be converted to a raising system and the subject brought back to the top.

While the rappel pick-off can be done by one person, the lowering pick-off needs at least two and is best performed with a minimum of three. As personnel increase, the level of safety also increases. With only two people, a lowering pick-off will have one person operating both the main line and the belay, which is not as safe as having a separate person managing the belay. An independent self-belay can be used in the two-person lowering pick-off. With three people, two can set up system anchors while the rescuer sets up their own gear and rigs the equipment they will need for the subject.

TEAM BASED PICK-OFF

While anchors are being established for the main line and the belay line, the rescuer readies their equipment. Set up the system by attaching a Prusik hitch to each of the lines about 2 feet (0.6 m) above the end and connect the Pick-Off Strap to both. Push the Prusik hitches up as far as the rescuer can reach and set the Prusiks. If a harness is required for the subject, attach the Lifesaver Harness to the end of the Pick-Off Strap. Take a helmet for the subject and any potentially needed medical equipment. The rescuer connects himelf to the Figure 8 loops in the

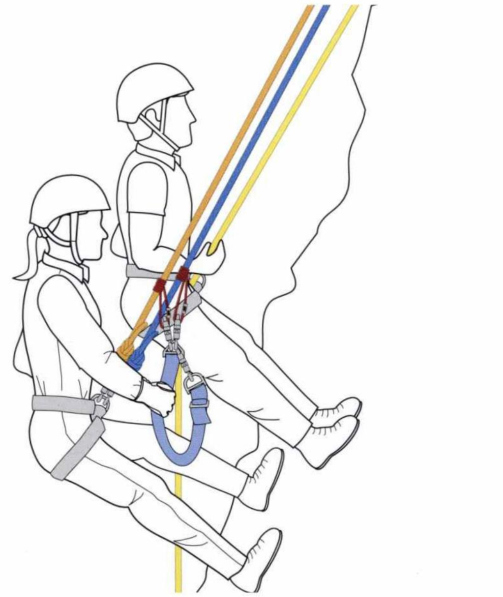




Note: This method also works with the MPD and the Rescue Rack.

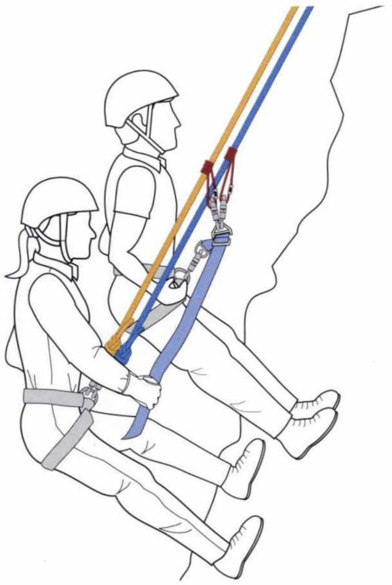
Step 1

Attach a Pick-Off Strap to the main line and the belay line using Prusik hitches.



Step 2

Stop with the rescuer's head about level with the subject's shoulder. Attach the D-ring of the Pick-Off Strap to the subject's harness. Adjust the strap and the hitches to remove as much slack as possible.



Step 3

With the subject in a comfortable and controllable position, continue the descent.

Figure 25-1: Team Based Pick-off

end of the main line and the belay. The lowering pick-off system then works like any lowering system.

Lower the rescuer to a position slightly above the subject but not close enough to tempt the subject to grab or jump at the rescuer. While the rescuer talks to the subject, providing reassurance and explaining what will be done, the rescuer readies the gear—either the Pick-Off Strap or the Pick-Off Strap and harness combination—for quick attachment to the subject.

When the rescuer is ready, lower them until their head is level with the subject's shoulder. This position allows the best access to attach a harness to the subject or to connect the Pick-Off Strap to the subject's harness.

Adjust the Pick-Off Strap to position the subject in front of the rescuer, providing enough separation so both people can walk up or down the face. This also allows the rescuer to control the subject and maneuver around obstacles.

On a vertical or free-hanging rope, adjust the Pick-Off Strap so that the subject hangs a few inches above the rescuer's thighs. The rescuer can hold the subject sideways, providing clearance from the face of the cliff. Small children can be turned so that their back is to the cliff face and they can hug the rescuer.

FREEING THE SUBJECT

If the subject is suspended by another system, such as a climbing rope or fall-safety lanyard, tension may need to be removed from the subject's system before that system can be disconnected. Rope and webbing could be cut by a safety knife or paramedic scissors, but

this will shock load the system when the cut is made. Also, there will always be the possibility of the wrong rope or webbing being cut, so using a safer, more secure way makes sense.

The adjustment in the Pick-Off Strap allows the slack to be removed before disconnecting the subject from their system. A strong rescuer may be able to lift a light subject and tighten the Pick-Off Strap to create enough slack to disconnect the subject's gear. A better method would be for the rescuers above to use a vector pull or a piggyback system on the subject's line to lift while the rescuer tightens the Pick-Off Strap.

Another method developed in the CMC Tower Rescue class uses a short mechanical advantage system, such as the CMC's AZTEK LT, to unweight the patient. The AZTEK LT is used in place of the Pick-Off Strap and allows both the connection to the subject plus a quick lift to free their equipment. An alternative is to connect the AZTEK LT or a mechanical advantage system between the anchor and the Brake Bar Rack. Once the Pick-Off Strap is connected to the subject, the rescuers on top can lift them to remove their weight from their system.

THE GROUND-BASED PICK-OFF

The team members operating the main and belay lines on a lowering pick-off do not need to be above the subject. There could be several reasons for this, depending on the location of the rescue.

- A paraglider stuck in a tree presents a situation where gaining access above the subject may be difficult and there is really no room to set up a system. A rope tossed over a branch above the subject can be used to pull up a high directional. The rescuer can then be pulled up to the subject and the system operators remain on the ground.
- A subject stuck in an industrial ladder cage may block access to any location above where a system can be set up. The rescuer climbs up the ladder, moves out of the cage to go above the subject, then back in to set up an anchor. The rescuer then pulls up the pulley and rope for a high directional and clips into the system. The system operators remain on the ground where they have good footing and room to work.
- On the Golden Gate Bridge we found the working surface on the cables to be narrow and very slippery from the usually present moisture. By one rescuer establishing a high directional, the pick-off could be operated by rescuers on the lower platform.

RAPPEL PICK-OFF

The rappel pick-off is an advanced technique for a small team rescue of an ambulatory subject. If enough rescuers are present, it is best to use a Team Based Pick-Off as it provides a belay and frees both the rescuer's hands to manage the subject.

Sometimes enough personnel or rope are not present to conduct a Team Based Pick-Off. Example would be a two-person crew working on a communications tower at a remote location. If one of the crew needs to be rescued, then the partner could use a rappel pick-off. Another example would be a two-person search team on a wilderness assignment. If their subject is found stuck below them, a rappel pick-off could be used.

On a rappel pick-off the rescuer must control the descent and manage the subject. By using an auto-locking rappel device such as the CLUTCH or the tactical rappel method, the need to stop and lock-off a descender is eliminated. This frees the rescuer's hands much quicker to deal with the subject. It also allows small adjustments if the rescuer finds the need to be a little lower when putting the subject in a harness.

Consideration must be given to the increased load when the subject's weight is transferred to the rescuer's rope. Depending on the rappel device and the rope diameter, adjustments might be necessary to provide sufficient control. A Figure 8 may be double wrapped or a wrap around the tie-off bar on a brake bar rack can be used.

The CLUTCH or other auto-locking rappel device works well it the device is rated for a two-person load. The CLUCH is certified for loads up to 600 lbs (272 kg). CMC cautions this is only for expert users with practice using the CLUTCH for this purpose. When performing a rappel pick-off with the CLUTCH, the rate of descent should be slow, no faster than a foot and a half per second: 1.5 ft/sec (.5 m/s).

Since a rappel pick-off is a rescue, an Independent Belay should be used. In Figure 25-2, we have left off showing the belay line for clarity of the pick-off process. If the team has a second rope or can double a single rope, and a belayer is not available, a back-up device or Prusik hitch can be used for the belay. If your organization practices Single Rope Techniques and would not have a belay, then greater expertise is needed.

All equipment should be in position before the rescuer starts down. Connect an AZTEK LT to the descender and clip the other end out of the way. A good place to put the end is into the carabiner attaching the load tender to the descender. If a harness is needed for the subject, attach it to the end of the AZTEK LT.

CMC PRO TIP

The CMC School and the International Technical Rescue Association both recommend an independent belay when teaching pick-off skills. A long-tail Bowline can extend the rescue lines, allowing for a back-up to the tender(s). An Alpine Butterfly would also work. While the tender does have two points of contact with the tender line, that does not constitute an independent belay.

The AZTEK LT works well on tower rescues and other situations where the subject must be lifted to disconnect them from their equipment. Figure 25-2 shows the subject on rappel, which is the common situation for practicing the rappel pick-off. On a tower or structure rescue, it is more likely the subject is supported by a fall arrest lanyard and will have to be lifted enough to disconnect them from the lanyard.

Rappel to the subject, stop and tie off the descender. Being in the right position will make a pick-off easier. If the subject is supported by a fall arrest system, stop just above them, then lean down and connect the load tender. This gives you more room to lift the subject in order to disconnect them from their equipment.

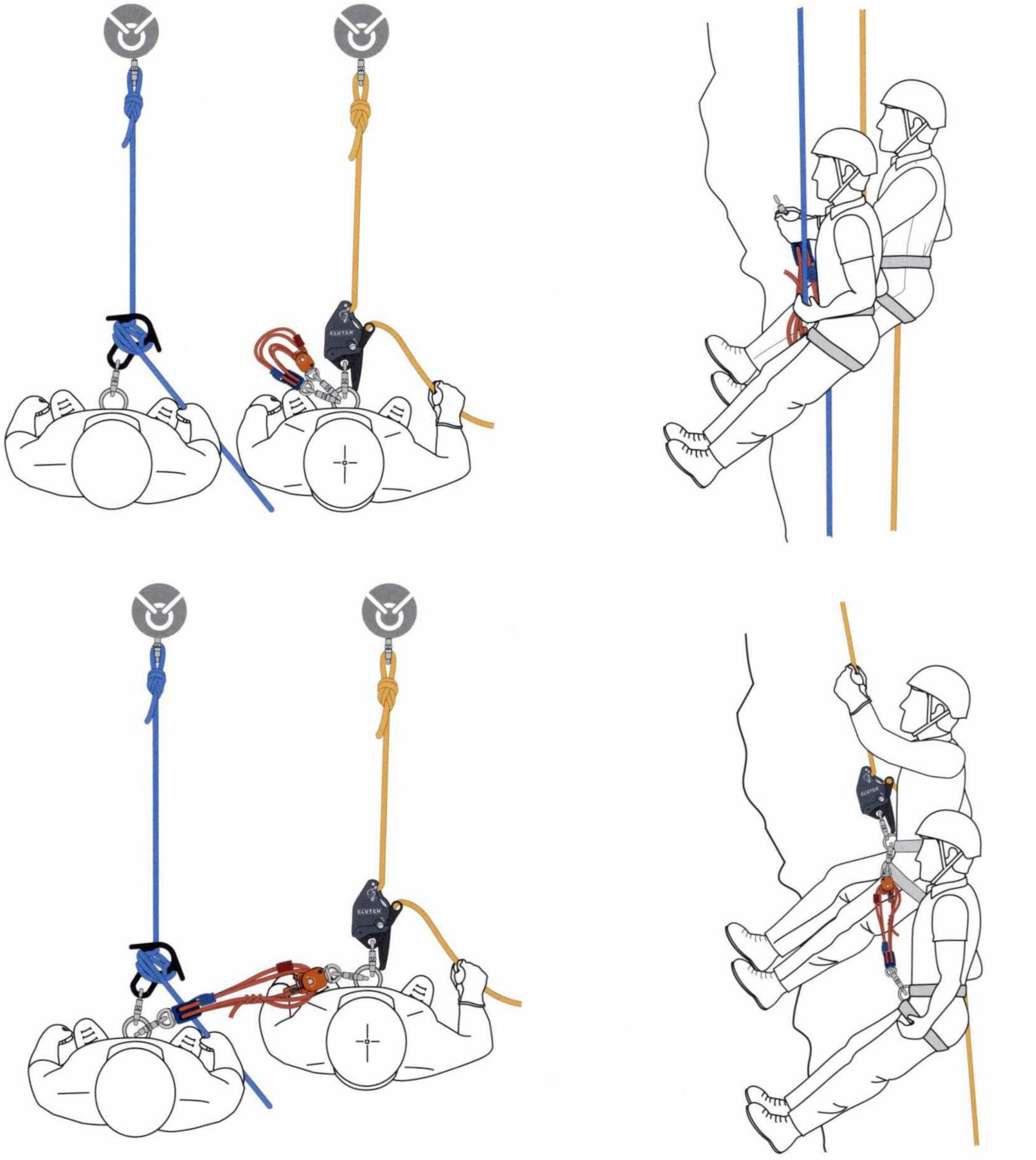


Figure 25-2: Rappel Pick-Off

Note: For clarity, the Independent Belay has been left off the above illustrations.

If the subject is supported by a rope, the rescuer should stop with their legs at the same height as the subject's hips. The rescuer can use their legs to control the subject's body position. If the subject is on a sturdy ledge, stop where you can put your weight on the ledge. This will be more comfortable and give the rescuer more control. If it is necessary to put a harness on the subject, it may require the rescuer to be positioned lower on the subject.

Attach the AZTEK to the subject's harness. Pull the end to remove as much slack as possible. By removing the slack, the shock load that will occur if the subject's support system fails or when their weight is transferred to the rescuer's system is reduced.

If necessary, carefully disconnect the subject from their rope or whatever is holding them in position, allowing their weight to transfer to the rescuer's descender. At this point the subject will be hanging a short distance below the rescuer. The rescuer is in the classic rappel position with their legs holding the subject away from the wall during the descent. The rescuer unlocks the descender and lowers the two of them to the bottom.

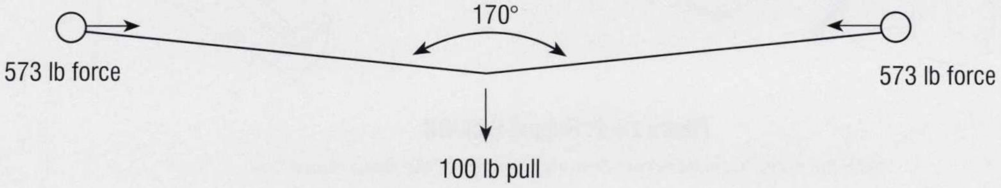
BELAYING THE SUBJECT

What if the subject is in fine condition and needs only protection from falling in order to climb down (sideways or up) from their position? Attaching a belay to the subject and allowing them to move under their own power is the least complicated evacuation. After reaching the subject's location, it can be determined whether or not this is feasible. First provide the subject with a harness and anchor them to an independent belay as described in Chapter 21. There are several options on how to proceed.

When the belay is ready and the subject understands what they are to do, tell the belay operator that the subject is "on belay." When the belay operator replies, start the subject on their way.

The Vector Pull

Need to lift the subject just enough to take the weight off of their system so it can be disconnected? The vector pull works on the principle that a perpendicular displacement of a line under tension greatly increases the tension. While this is not good for a high line, it can be used to lift a load slightly. With the rescuer and the subject supported by the rescuer's line, team members can lift the line, by pulling it perpendicular to the direction of the rope. A small displacement will lift the rescuer and the subject, possibly enough to disconnect a carabiner, freeing the subject from their system. While the further you pull does lift the subject higher, the mechanical advantage gained by the vector pull decreases rapidly as the interior angle decreases.



PART
06
Rescue Techniques

CHAPTER
26
High Angle Litter Evacuations

LEGEND: Anchor Grip Load

TERMINAL LEARNING OBJECTIVE

The student will rig and tend a litter in a high angle environment.

ENABLING LEARNING OBJECTIVES

1. Demonstrate how to properly attach a litter bridle and tender line for a high angle evacuation
2. Demonstrate how to negotiate the edge with a loaded litter
3. Demonstrate how to properly tend the loaded litter during a high angle evacuation
4. Demonstrate how to properly use a vertical litter harness for a high angle evacuation

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.2.13 | 5.2.14 | 5.2.15 | 5.2.16 | 5.2.17 | 5.2.18 | 5.2.19 | 5.2.23 | 5.3.4

LITTER EVACUATIONS

We define a high angle evacuation as a situation where the angle is so steep that the weight of the litter and tenders is borne primarily by the rope (see Figure 26-2 and Figure 26-3). Sometimes called vertical evacuations, high angle evacuations are used on cliffs, overhangs and the sides of structures. For patient comfort and for easier tending by a single person, the litter is usually in a horizontal position. A narrow passageway or rockfall may require the litter position to be vertical and additional tenders may be required.

A low angle evacuation, sometimes called a scree evacuation, does not have a steep enough angle for the litter to hang from the rope, (See Chapter 27). The tenders support more of the weight of the litter but a rope system is still needed to move the litter and tenders.

There is no definitive angle that determines the difference between a low angle and a high angle evacuation. The angle for evacuation from a building or a highway embankment is usually pretty consistent. The terrain angle during an evacuation on a mountain roadside could change several times on the way up. It really comes down to how many tenders are needed to support the litter; more on a low angle, less on the high angle.

We refer to both a high angle and a low angle situation as technical evacuations because rope rescue techniques are used to move and belay the litter. A carryout that relies mainly on the tenders to support the litter weight and provide movement would be a non-technical evacuation, often using a litter wheel to support the litter. However, a belay may be used on a non-technical evacuation to catch the litter if the tenders lose control. Terrain conditions also determine the type of evacuation. The more difficult the footing, the more likely a rope system will be needed.

CMC PRO TIP

The CMC School and the International Technical Rescue Association both recommend an independent belay when teaching litter tending skills. A long-tail Bowline can extend the rescue lines, allowing for a back-up to the tender(s). While the tender has two points of contact with the tender line, that does not constitute an independent belay.

The Litter Harness

A properly designed pre-rig litter harness sets up fast and provides a greater range of adjustment than one improvised at the scene. If working primarily on rock or cliffs, the longer legs of this harness provide a wider range of adjustment, allowing the rescuers to handle variations in the terrain. When working with a helicopter door or a building window situation, short harness legs are desirable. Pre-rigs generally consist of four or six legs plus tender lines for one or two tenders.

Whichever set-up is used, it will still have to be tied onto the main line and belay. Tie a Figure 8 loop in the main line and the belay line. Most rescuers use two carabiners to connect the

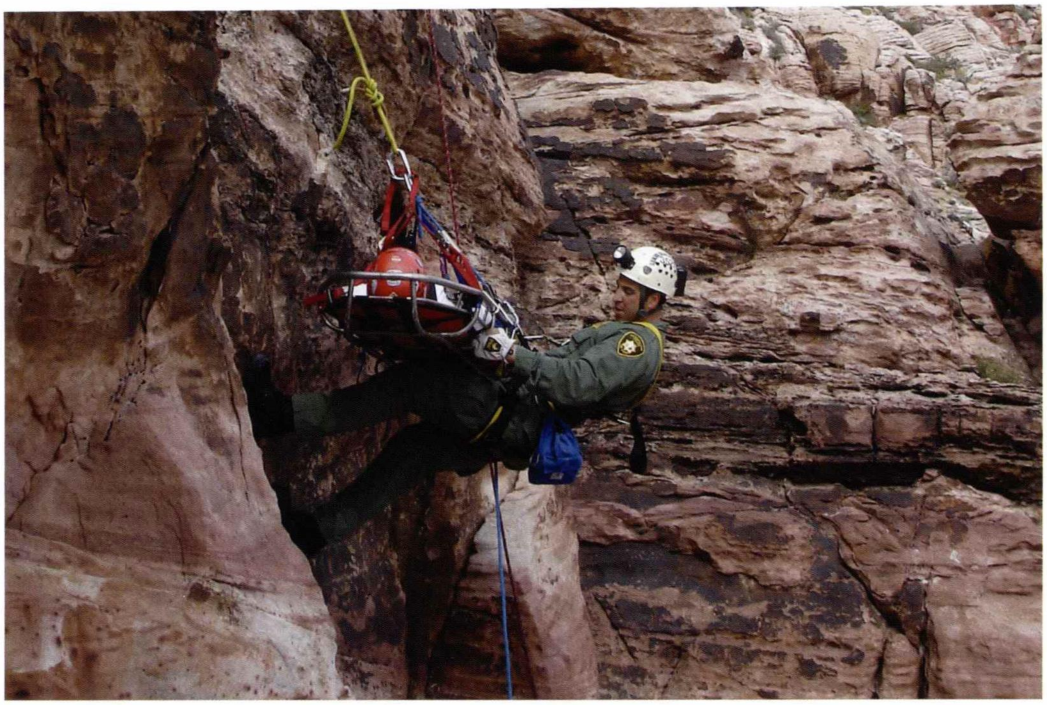


Figure 26-1: High Angle Evacuation With a Horizontal Litter

system to the litter harness. Some teams prefer to clip both lines into both carabiners. This provides a backup if one of the carabiners should fail. Others prefer that the main line and the belay each clip into their own carabiner, which makes it a lot easier if one of the lines needs to be removed while the other is loaded.

Using a long-tail Bowline at the end of the main line and the belay line allows a back-up connection to the litter or the tender. One tail would go either to the head of the litter or to the patient's harness, if one is worn. The other tail can go to the litter tender. Over the years we have found both to overly complicate the system and reduce flexibility. We are not seeing failures with the litter or litter harness and any such backup would need to be long enough to allow adjustment of the litter harness legs. For the tender, the system has two points of attachment to a short line that is always visible and protected by the litter.

Litter Tending

The tender's weight is supported by the ***tender line***, a length of rope approximately 10 ft (3 m) long that attaches to the top of the litter harness. By attaching themselves to the line with an ascender, the tender can move up and down to place themselves in the best position. Any ascender or a Prusik hitch will work but we have found that a spring-loaded ascender works best. A knot at the bottom of the tender line will prevent the ascender (and the tender) from sliding off the line if for some reason the ascender fails to grip.

A second ascender connected to the rope above your harness ascender, plus an etrier, will make movement up and down the tender line easier. Stand up in the etrier to unload the ascender on the harness. Pull on the end of the tender line below the ascender to move it up the rope to the desired location. To go down, just open the cam, lower to the desired position and transfer weight from the etrier back to the ascender. A runner from the tender's harness to the ascender with the etrier provides the second point of attachment. The CMC Etrier with Tie-In is designed for this purpose.

The tender's position will let them keep the litter away from the wall but still allow access to the patient. A good location to place the harness ascender is just below the railing and then adjust it as needed. Keep your feet high when working past an overhang. The tender's toes should be nearly level with the top of the litter as they descend past the lip. The long tail on the tender line will allow them to go below the litter if they need to clear rock or brush out of the way.

An AZTEK LT system can also be used for tending the litter. Connect the AZTEK to the top of the litter harness and the other end to the tender's harness. The rope exiting the pulley should descend down from the upper pulley so the tender can pull down to raise their position. Connect only the lower Prusik hitch, it can be tended while letting rope out to lower the tender's position.

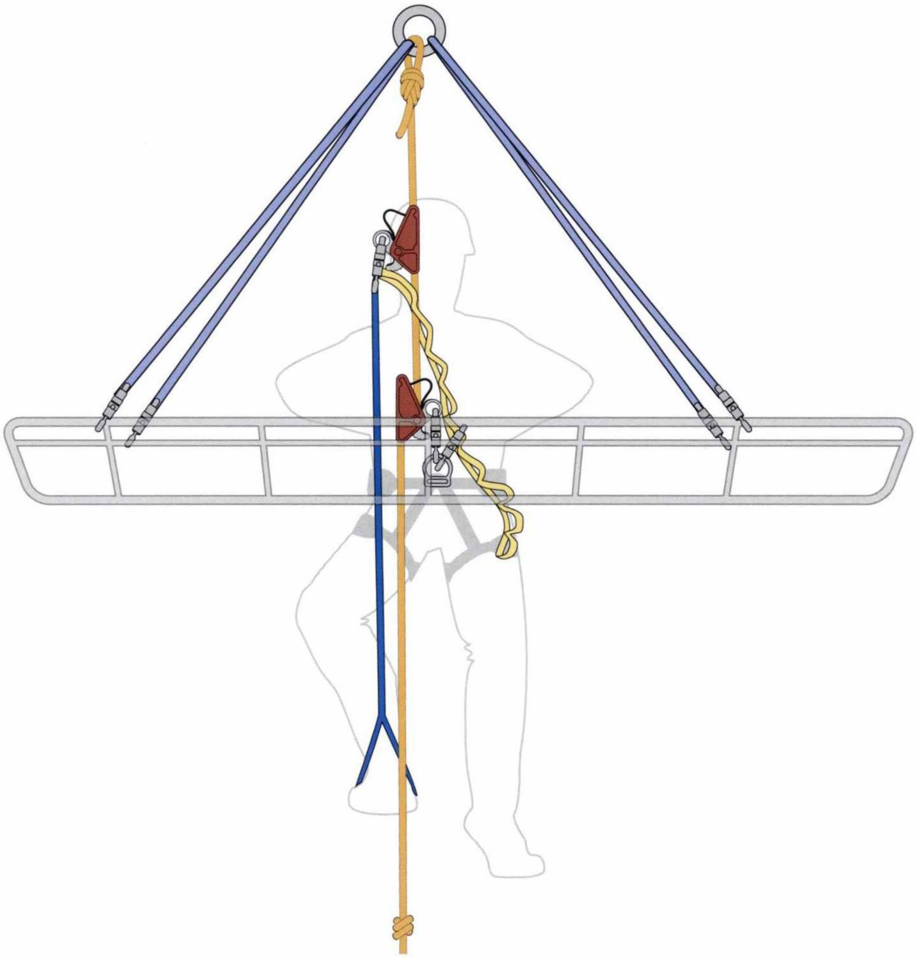


Figure 26-2: Tender Using Ascenders

The tender hangs near the center of the litter and movement toward the head or foot creates a gravity-fighting pendulum. If the tender needs to be closer to the patient's head, a litter strap connected to the end of the litter and to the tender's harness will help hold the tender in position. A multi-loop strap or a web sling can be used but does not adjust as easily.

Working the litter past an overhanging edge is difficult. For a tall litter tender, it may be possible to be low enough on the tender line to place the tender's feet up high near the far rail of the litter to maintain clearance. A better solution is to use the ***high-tender*** position. Moving the tender's rope grab up the tender line until the tender is above the litter allows the tender to keep the litter a greater distance from the structure wall or cliff face. To get high enough, the tender may need to clip directly into the O-ring on the litter harness or connect a Prusik hitch to the main line above the knot. The legs on the litter harness can be lengthened to provide clearance between the tender and the patient.

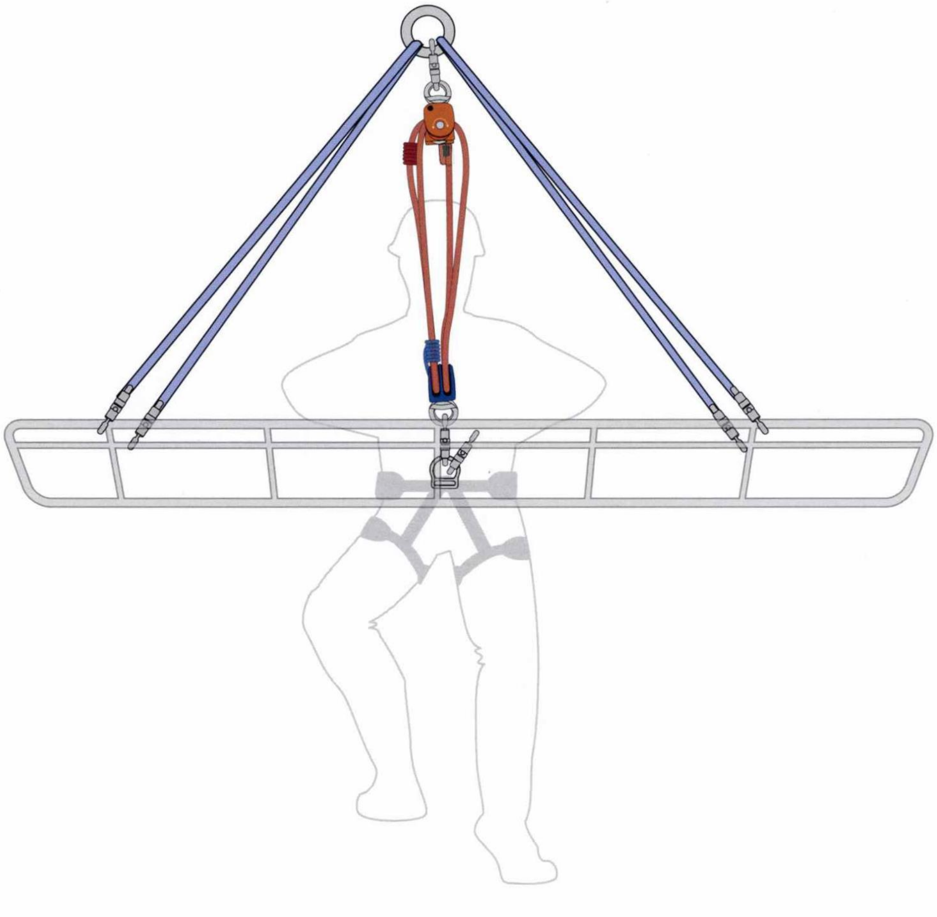


Figure 26-3: Tender Using the AZTEK LT

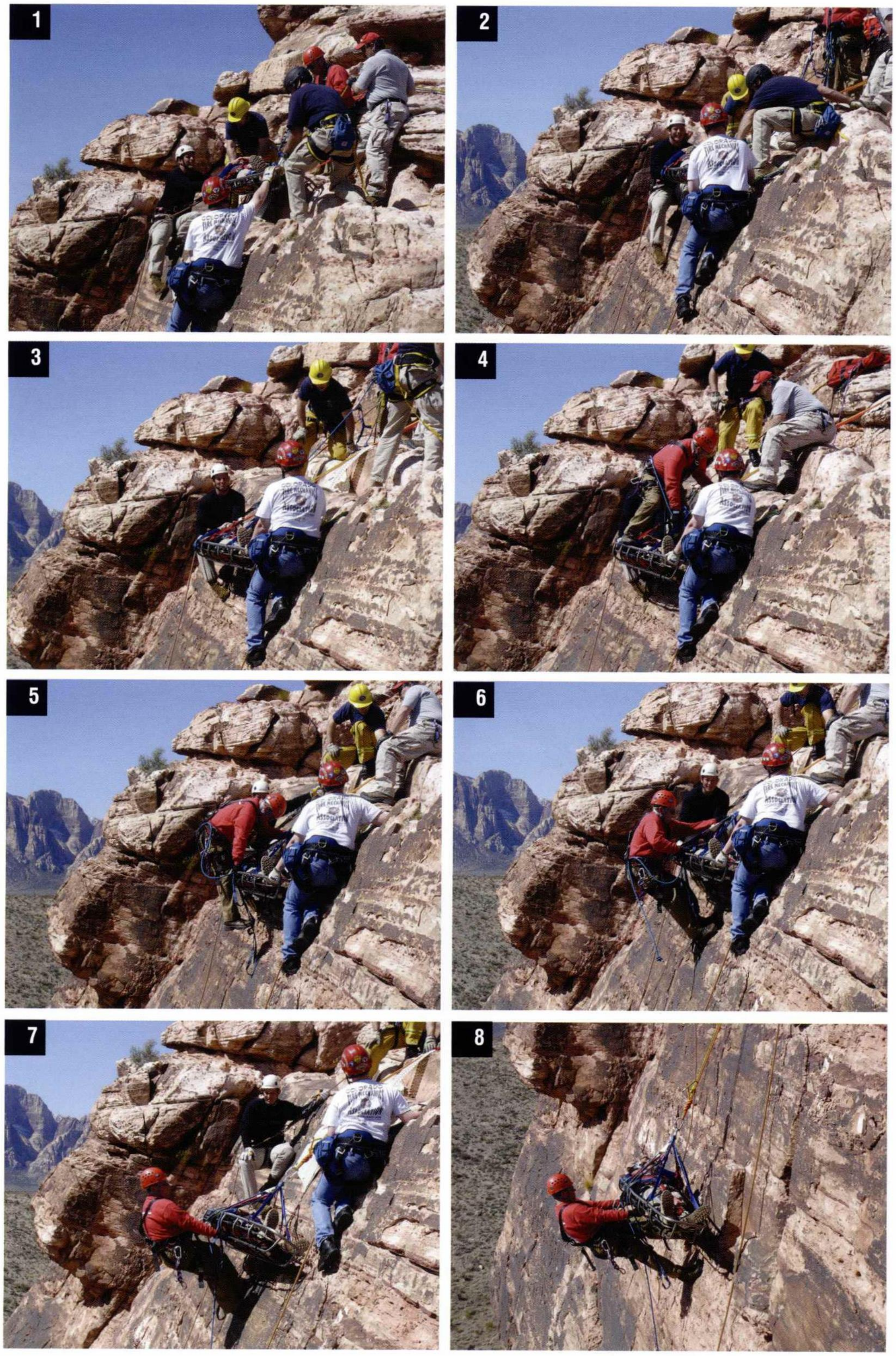


Figure 26-4: Two edgeman go over the edge on rappel lines and assist in moving the litter over the edge. Next, the tender climbs down using the litter rail and the etrier on the tender line. When the tender is in position, the lowering can begin.

Edgework

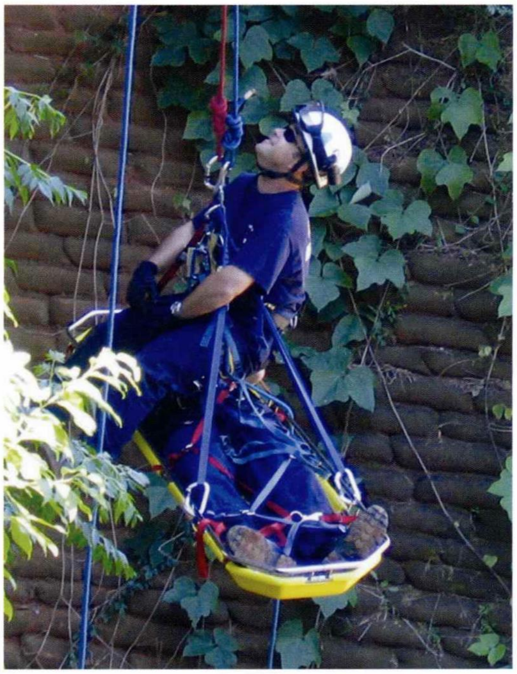


Figure 26-5: High-Tender Position

Moving a litter over the edge of a building or a cliff is difficult because the tender is pulling directly against the pull of the main line. A strong tender can pull hard enough to counter the pull of the rope and ease the litter over, but this puts a lot of stress on the system and on the tender. Also, it creates the possibility of dropping the litter, causing injury to the tender or the patient and shock loading the system.

The method we now find works the best is to put two edgemen over the side on rappel lines. They should have the necessary equipment to either rappel down or ascend back up when finished. The tender connects near the end of the tender line and runs the line over the top of the litter harness. The litter is moved to the edge and the edgemen lower the litter over the edge until it is resting on the system. The tender then climbs down over the litter and into position using the etrier on the tender line if needed.

On a raising, the tender may be able to place their feet high enough that they can lift the litter over the edge. If not, then the reverse of the above will work. When the litter is just below the edge, the tender can climb up. The edgemen, with the help of the haul team, move the litter over the edge.

On difficult edges, and if time permits, consider using a high directional. A natural high directional, such as a tree, may allow a higher connection for the haul line, or an Arizona Vortex or A-frame could be set up at the edge.

Protecting the Airway

How do you clear an airway when the patient is tied in and the litter is hanging in the air? We recommend carrying a V-VAC™ Suction Unit or other portable suction device. The patient can be placed in a left lateral recumbent position if a tender is not able to protect the airway. This becomes a judgment call between spine protection and airway protection. Several teams are using a pair of full-body vacuum splints to provide a stable platform with good spine protection while the patient is in a recumbent position.

Multiple Tenders

We have seldom found a need for more than one tender in a high angle evacuation with the litter in a horizontal position, although in some places using two tenders is common. Because of the extra loads on the system, additional tenders should only be used when absolutely necessary. One case is when a medic must be with the patient and a second person is needed to manage the litter. This could happen if the medic is not experienced in high angle

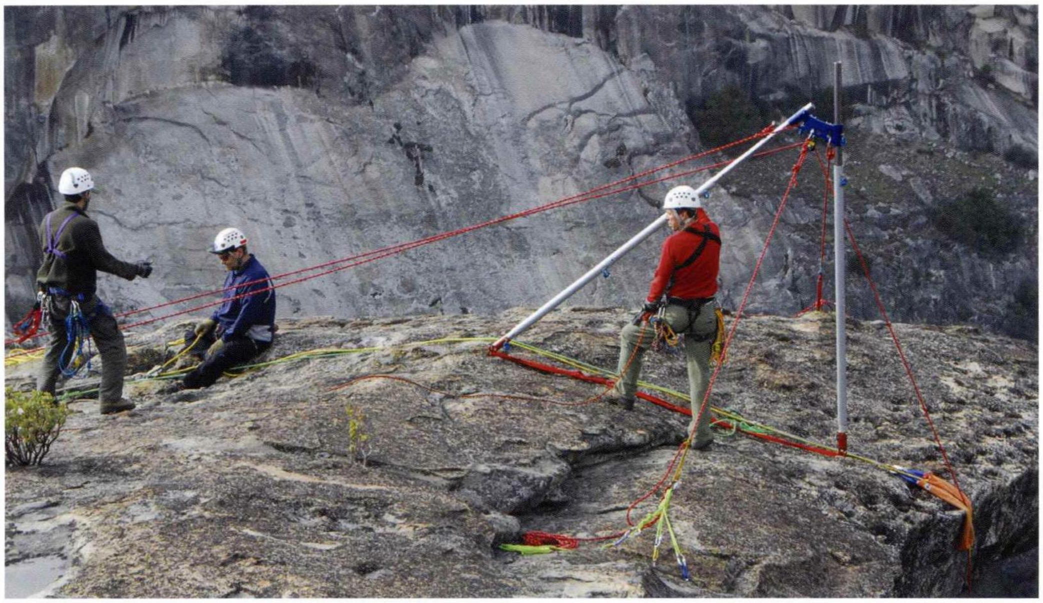


Figure 26-6: Arizona Vortex set as a sideways A-Frame to ease edge transition

evacuations or when the patient requires the medic's full concentration. If low angle sections are encountered in a primarily vertical raising or if the patient care requires a horizontal litter position in a lower-angle evacuation, an extra tender or two may be required. Keep in mind, a second tender adds more body weight that the system must support. One person will increase the overall load by nearly 50% and it will require additional pulling force from the raising team.

To rig for two tenders, add a second tender line beside the first. Each tender will be on their own line. If the tenders find that they are being pushed together too much, a runner connected between the tender's line and the litter near each end will hold them in position. It is better to attach a CMC Adjustable Litter Strap to each end, so they can easily adjust their positions.

If there is a situation that needs two tenders but also a necessity to limit the load on the litter, the medic could use a separate line. If the medic is lowered or they rappel down to the patient, then they can come up on the line they used to go down. If they have a fixed line, they can ascend it as the litter is raised. A control line (CMC Adjustable Litter Strap works well here) to the head of the litter can serve as an independent belay.

Vertical Evacuation with an Inline Litter

If the evacuation is in a narrow, steep gully, in an air shaft or between crevasses in a cave or cliff, the litter may have to be set on end so that it is in line with the direction of movement to make it fit. This position is very common in confined space evacuations. The disadvantage to this solution is in the patient's comfort. They will no longer be lying in the litter but hanging in it.

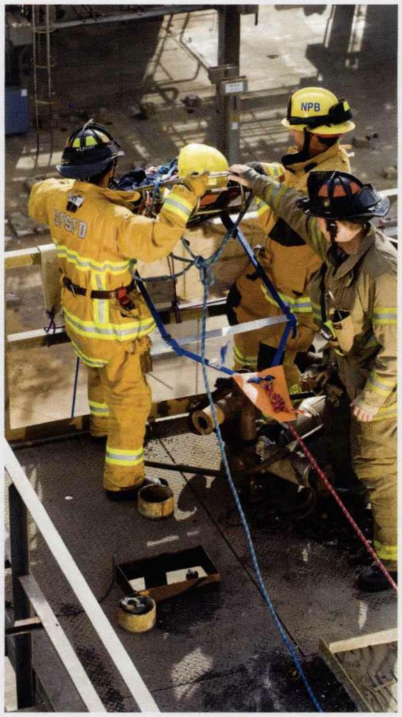
Because of this, patient packaging becomes important both for comfort and security. The weight of the patient will be supported primarily by the pelvic tie-in while avoiding placing weight on any injuries (see Chapter 12 for specific details).

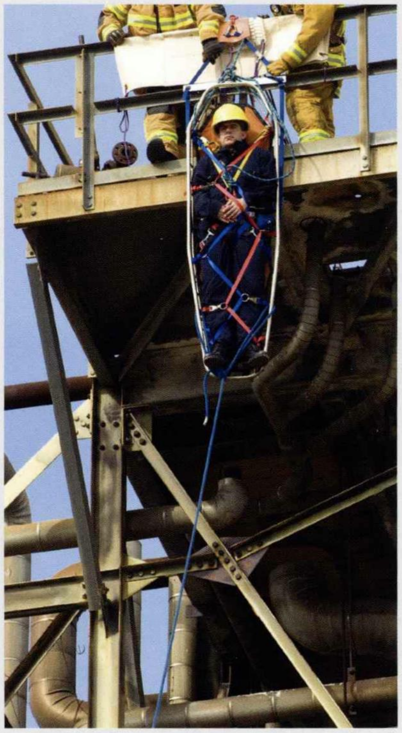
Because it connects to the head of the litter, a low angle litter harness will work best. In the CMC School, we connect our Vertical-Lift Litter Harness to vertical litter tubes located near the patient's pelvis. This allows the head of the litter to rise above the edge or the opening and then be tipped, making handling much easier.

The tender can connect into a litter rail with a litter strap or even better to a tender line with the same type rigging as in a vertical evacuation. This provides the tender with a wide range of movement. If a Figure 8 loop or Alpine Butterfly in the main line is used, a 15 to 20 ft (4.5 to 6 m) tail can be used for the tender line.

If the angle is not vertical, one tender alone will not be able to keep the litter away from the side. This is because the tender is on one side of the litter and someone else is needed on the other side for balance. It is better to use a separate tender line attached to the main line for the second tender rather than a tail on the belay line (if possible). Because the belay line is not being pulled by the raising system, the belay line operators would be pulling both the weight of the tender and the belay line. An issue with a main/belay system but not with a twin-tension system.

Inline Litter and the 90° Edge





The following set-up and procedure will make negotiating a 90° edge easier for the rescuers and more comfortable for the patient. This procedure requires a heavy-duty litter. A light-duty steel litter or a plastic litter may bend, resulting in serious harm to the patient.

Step 1
Attach a CMC Vertical-Lift Litter Harness to the vertical tubes on the litter near the patient's hips. Attach the belay line to the top rail at the head of the litter. Connect the main line to the litter harness.

Step 2
Place an edge pad or other canvas tarp that is as wide as the litter over the edge to prevent the litter harness from abrading.

Step 3
Lower until the litter begins to pivot over the edge. Use the belay line to control the head of the litter as it pivots. Tag lines running down from each corner of the foot of the litter can be used by rescuers below to help stabilize the movement of the litter.

Notes

PART
06
Rescue Techniques

CHAPTER
27
Low Angle Litter Evacuations

TERMINAL LEARNING OBJECTIVE

The students will rig and tend a litter in a low angle environment.

ENABLING LEARNING OBJECTIVES

1. Demonstrate how to properly rig a litter and tender attachments for a low angle evacuation.
2. Demonstrate how to negotiate the edge with a loaded litter.
3. Demonstrate how to properly tend a litter in a low angle evacuation.

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.2.21 | 5.2.22

LEGEND: Anchor Grip Load

LOW ANGLE EVACUATIONS

A low angle evacuation, sometimes called a scree evacuation, does not have a steep enough angle for the litter to hang primarily from the rope. The tenders support more of the weight of the litter but a rope system is still needed to move the litter and tenders.

A horizontal litter position with two tenders provides the best patient comfort and may be less stressful for the tenders. This is used often with the roadside or highway embankment evacuation. It is very effective if the angle becomes near vertical or varies on the way up.

On a lower angle, a head-up litter in line with the rope system, four tenders may be needed to support the weight of the patient. The CMC Litter Strap is designed for this purpose. By connecting the tenders to the litter, they can lean back, allowing the system to help lift the litter off the ground. A Multi-Loop Strap or a Purcell Prusik would also work to connect the tenders to the litters.

Because more of the weight of the litter and patient are on the tenders, low angle evacuations typically use multiple tenders. There are couple of ways to orient the litter depending on the terrain and the available personnel.

Horizontal Litter

One option is to use a horizontal litter and position the tenders on the downhill side of the litter. Generally at least two tenders are needed, and sometimes three.

Rig the tender lines to the connection point at the top of the litter and each tender connects in with an ascender or Prusik hitch. If you use the long-tail Bowline, the tails can be used for two tenders.

In practice, the tenders lean back and hold the litter away from the cliff side. Adjust the Prusik hitch or ascender for the most comfortable position and lean back. The legs of the litter harness must be adjusted to keep the patient as level as possible and not tipped towards the cliff.

Vertical Litter

In cases where the terrain is narrow, such as a gulley, or more than three tenders are needed, then a vertical orientation of the stretcher is used. The CMC Low Angle Litter Harness can be used to attach the litter to the rope system.

Or the main line can be tied directly to the litter using a Portuguese bowline as shown on page 93. The Portuguese bowline spreads the load across several structural points on the litter, which is preferred over a direct connection, such as just clipping a carabiner around the rail.

We have found on low angle evacuations that tying the tenders directly to the litter works best. Even though this tie-in is under load, it is technically a belay as the tender's weight is supported by their feet. By leaning back into their harness, the tenders can use their weight to further lift the litter.

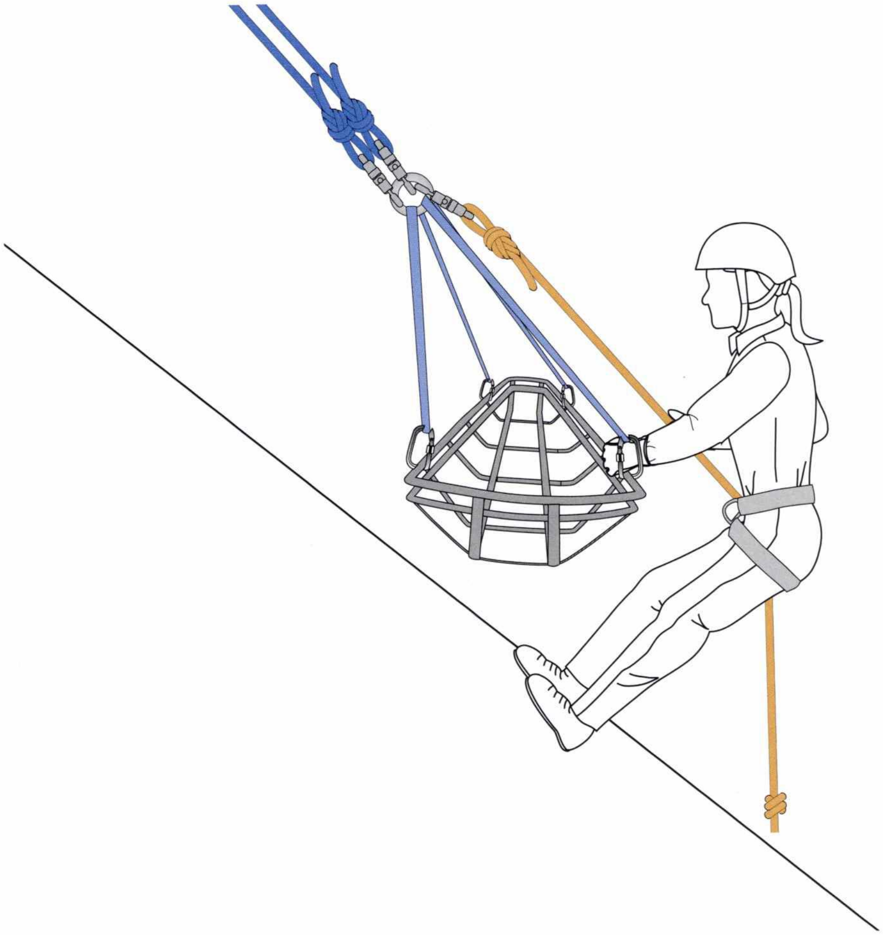


Figure 27-1: Low Angle Evacuation with a Horizontal Litter

The CMC Adjustable Litter Strap allows easy adjustment to the optimum distance from the litter. This will provide the best comfort and balance. The quick adjustment of the buckle allows easy changes to position, and if necessary, the tender can quickly extend the strap if they have to move away from the litter to avoid a snag or to set the litter down. Alternatives include the CMC Multi-Loop Strap, a web sling or a Prusik loop. Connect the litter strap to a vertical post forward of your position at the rail (see Figure 27-2). When the litter starts up, the tender should lean back into their harness and let the system pull them up the hill. This lets the legs do most of the work rather than the rescuer's arms. The length of the strap can be adjusted as needed to place the tender in the best position.

When lowering, the tenders walk backward in a position similar to rappelling. Pull on the litter if the angle is not steep enough, particularly if the litter is empty. By letting out on the litter strap the body can be turned sideways and both a stronger pull and a better view can be obtained. When conditions change, a pull on the strap will reposition the tender.

The medic should be at the patient's head to monitor their condition and provide reassurance during the evacuation. If the patient and litter need to be rolled to clear the patient's airway, the litter strap will let the tenders on the down side move out of the way.

The number of tenders depends on the steepness of the terrain. In most cases, three or four seem to be the right number to support the litter but not overload the system. Flatter terrain may require additional tenders, but then this is getting closer to a carryout with a belay than a low angle evacuation.

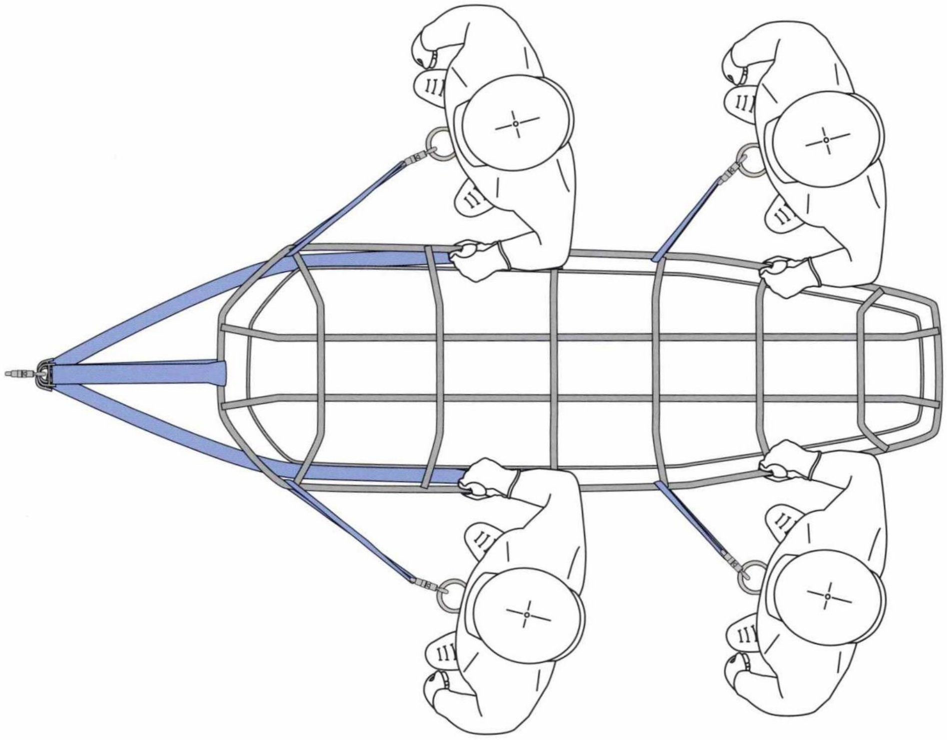


Figure 27-2: Low Angle Evacuation with a Inline Litter

A litter wheel used in low angle evacuations greatly reduces the load the system has to pull. First, fewer tenders are needed as their primary purpose is to balance the litter. Second, the wheel holds the litter off the ground so the leaning back by the tenders to help lift the litter is eliminated.

The wheel can be more of a problem than it is worth if the litter has to go over a lot of boulders or logs or through dense brush. In a narrow V-shaped gully, there may not be enough room at the bottom for both the wheel and the tenders' feet. Fewer tenders spaced farther away from the wheel may work or perform the evacuation without a wheel.

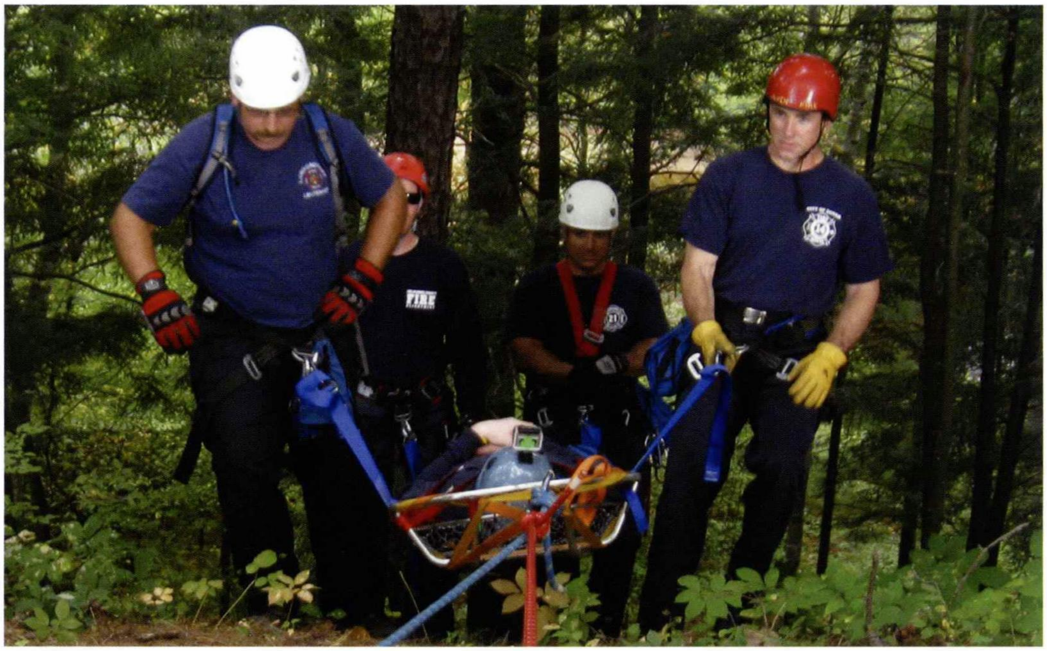
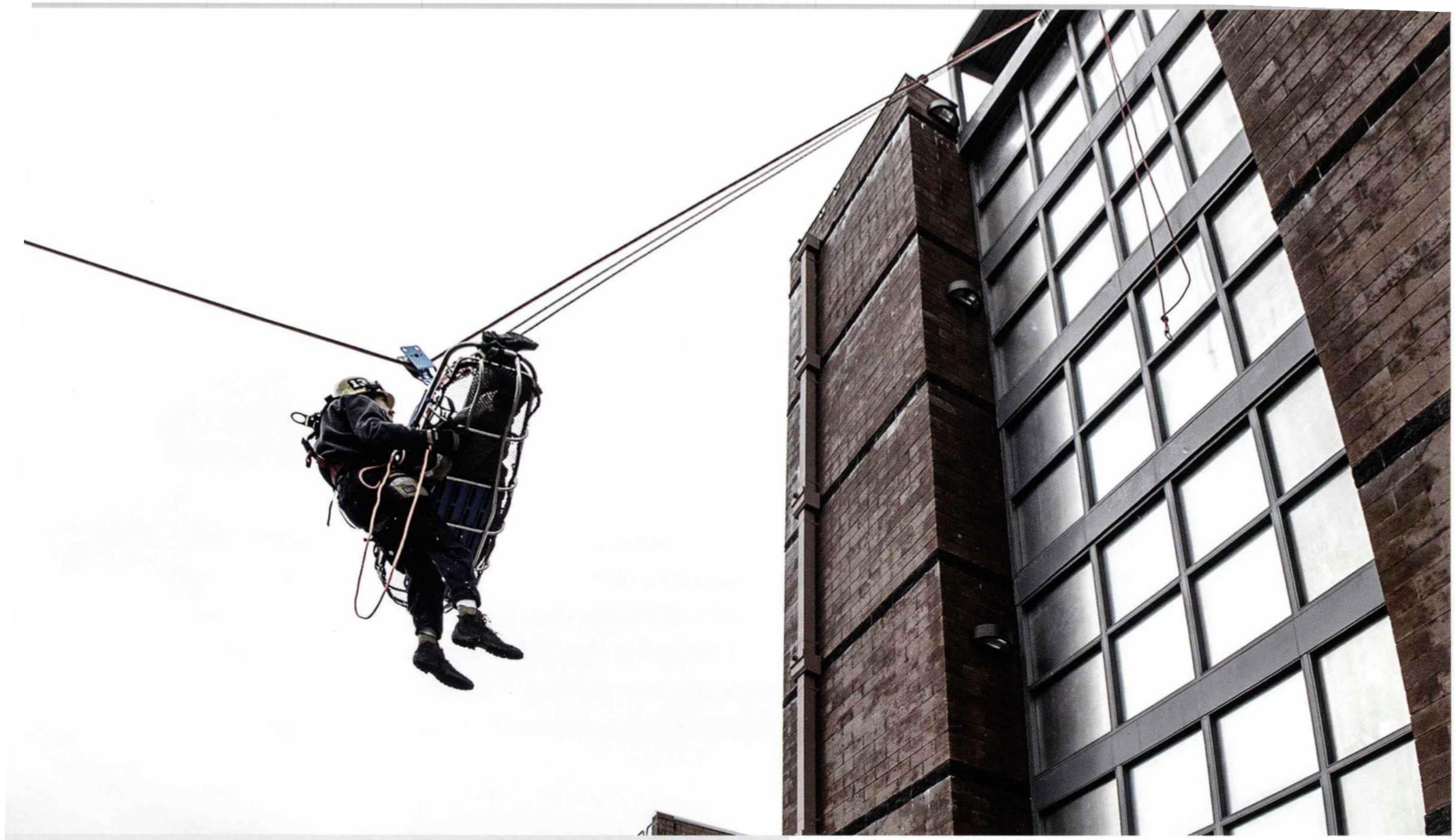


Figure 27-3: Litter Straps Used in a Low Angle Evacuation

Notes



PART
06
Rescue Techniques

CHAPTER
28
Guiding Lines

LEGEND: Anchor Grip Load

TERMINAL LEARNING OBJECTIVE

The student will construct and operate a guiding line system.

ENABLING LEARNING OBJECTIVES

1. Explain the difference between a guiding line and a high line system
2. Demonstrate the proper rigging and operation of a guiding line system

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.3.5 | 5.3.6

A ***guiding line*** system combines a lowering system and a tensioned line to lower a litter while keeping the litter away from the surface. In many areas, the boulders at the bottom of a cliff face present a difficult transport to flat ground. Large hotels or office buildings can be of the wedding cake design with the footprint of the lower floors much larger than the top floors. The surface area below a structure may have smaller structures or rubble from collapsed buildings that would require additional lowering systems. Industrial facilities have pipeways or other equipment that prevent a straight lower. By using a guiding line system, the litter can be moved over these obstacles.

While a guiding line system looks similar to a sloping high line, the definitive difference is that the guiding line system eliminates the need for a control line at the lower end. It is not needed because the load stops at its lowest point and the litter does not need to be pulled up to the finish. While a guiding line system could be used in conjunction with a mechanical advantage system to raise a litter, the most common use is for lowering. The use of a guiding line enables the litter or patient to be lowered untended which saves time and reduces the load on the lowering system and guiding line.

SETTING UP A GUIDING LINE SYSTEM

There are two parts to a guiding line system: the guiding line and the lowering system. The rope length for the guiding line will need to be longer than the distance to be covered to allow for the mechanical advantage system at the bottom. Some situations require the tensioning system to be at the top but usually the bottom works best.

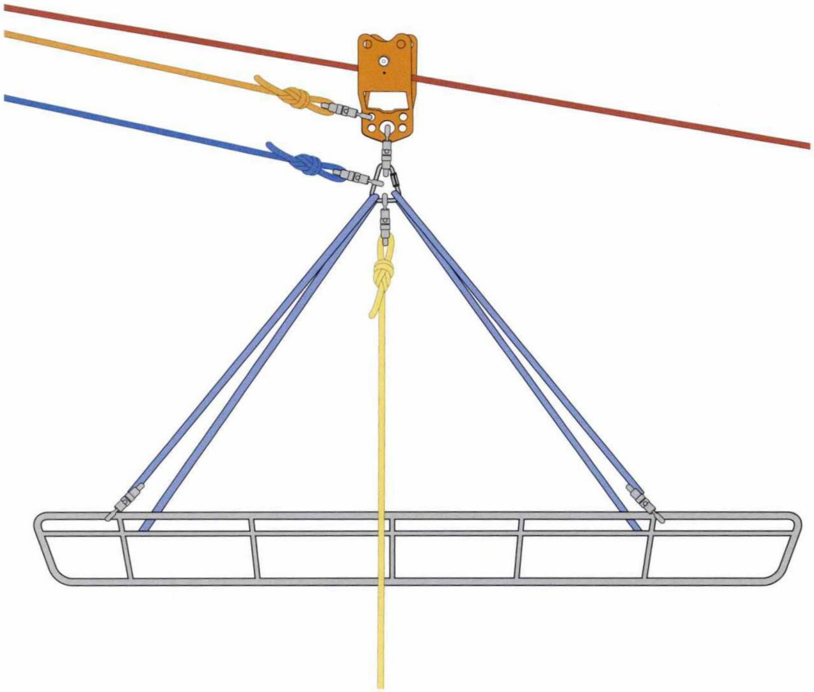


Figure 28-1: Litter Set-Up for Guiding Line

Set-up starts by attaching the guiding line to a secure anchor at the top, preferably with a high-strength tie-off or other connection that eliminates the knot. The guiding line should be positioned high so that it is well above the launching point, allowing it to lift the litter off of the surface to clear any edge. For example, if the litter is going out a window, you may need to anchor the guiding line at the floor above. Then, when the line is tensioned, it will lift the litter and not let it drop as it leaves the window.

Next, pass the guiding line to the personnel that will be setting up the lower end. Depending on the distance involved, you may be able to toss the rope or you may need a line gun to shoot a messenger line over the area you are trying to cross. Another option would be for a rescuer to rappel to the bottom and work their way through the boulders or urban obstacles that are in the way; one person on foot moves a lot more easily than a loaded litter. While the mechanical advantage system can be set up at the top of the guiding line system, usually there is more space available at the bottom end. It may also be quicker if personnel are already located at the bottom.

Set up an anchor and connect the guiding line to it using a mechanical advantage system. The further out the bottom anchor is from the bottom of the slope, the better the lift of the guiding line. Unless you have plenty of personnel, a 5:1 M/A system will be needed to tension the guiding line. A steeper sloping line requires less force to tension so a 3:1 M/A may work. Use the same tensioning estimates as for high lines: for ropes with no knots a factor of 18 for NFPA, G-rated ropes and a factor of 12 for NFPA, T-rated ropes. The factor equals the mechanical advantage multiplied by number of haulers tensioning the system.

At the top, set up a main line and a belay line. Leave enough room between the anchors and the edge for the litter and the personnel working around it. A high-line carriage or large pulley is placed over the guiding line and the litter harness is attached to it. Connect the main line to the carriage or pulley. This keeps the pulley aligned with the track line when maneuvering the litter around obstacles. Connect the belay line to the carriage or to the O-ring on the litter harness.

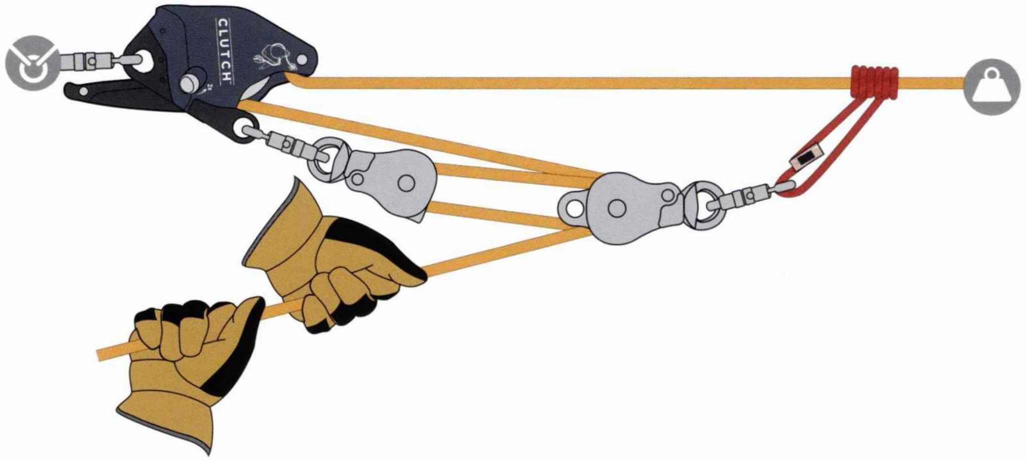


Figure 28-2: Bottom Set-Up with Mechanical Advantage System

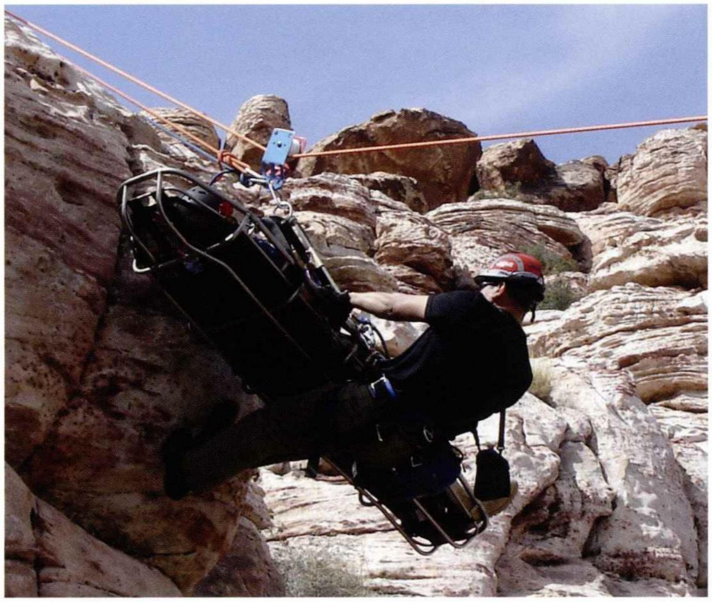


Figure 28-3: Load Primarily on the Lowering System

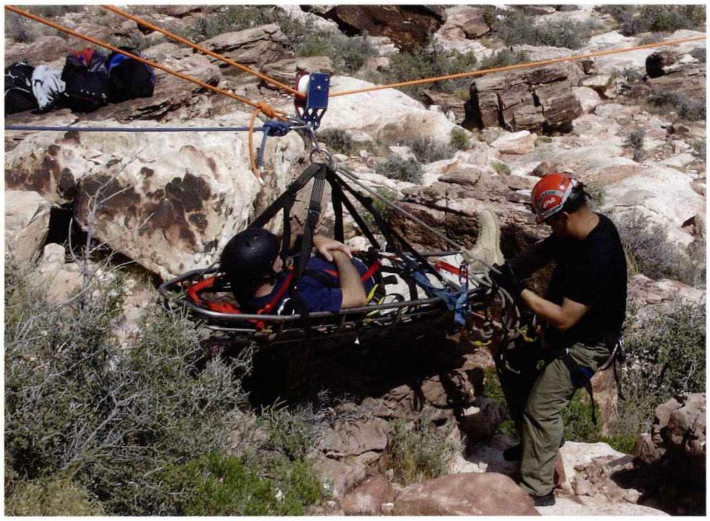


Figure 28-4: Load Primarily on the Guiding Line

CMC PRO TIP

If the tender lifts the basket a little, it is easier for the guiding line team to add tension.

OPERATING THE GUIDING LINE

At the start, the guiding line system operates basically as a lowering system with the guiding line pulley acting as a moving high anchor point. If the guiding line is positioned well above the edge, tensioning it will lift the litter up and out over the edge. With a tended litter, use just enough tension on the guiding line to keep the carriage out of the way of the litter and tender. During this part of the lowering, the system is acting as a conventional lowering system with a main line and a belay. Failure of the guiding line at this stage would have no impact on the system.

The tender keeps the litter away from the wall. On an untended litter, use just enough tension on the guiding line to keep the litter from contacting the wall or any obstacles.

As the litter reaches a point where it needs to be pulled away from the face or suspended over the surface, tension the guiding line to lift the litter. Use just enough tension to clear any obstacles.

When the litter reaches terrain that allows the tender to walk, they can disconnect from the tender system and significantly reduce the weight of the litter and thus the tension needed in the guiding line to lift the litter. The tender then walks beside the litter and helps guide it around obstacles. Tension in the guiding line can be increased to lift the litter over obstacles and then released to keep the litter low to the ground.

By keeping the litter just a foot or two above the surface, the need for a second line as a backup is eliminated. The exposure to a fall is limited and the likelihood of injury minimal while the litter is near the ground.

SKATE BLOCK SYSTEM

A Skate Block System is a variant of a Guiding Line. It is useful with evacuations from vertical structures, such as towers, while the Guiding Line is used for low angle or more horizontal operations. Like the Guiding Line, its function is to keep the load away from the structure or surface to help prevent entanglement. That means the load does not need a tender to "steer" it, allowing for a faster operation that requires less personnel.

In most rescue situations, the Skate Block system is used for lowering but it can be used for raising as well, such as when moving a litter up to the subject. What makes a Skate Block different from a traditional Guiding Line system is that it doesn't require an additional rope for

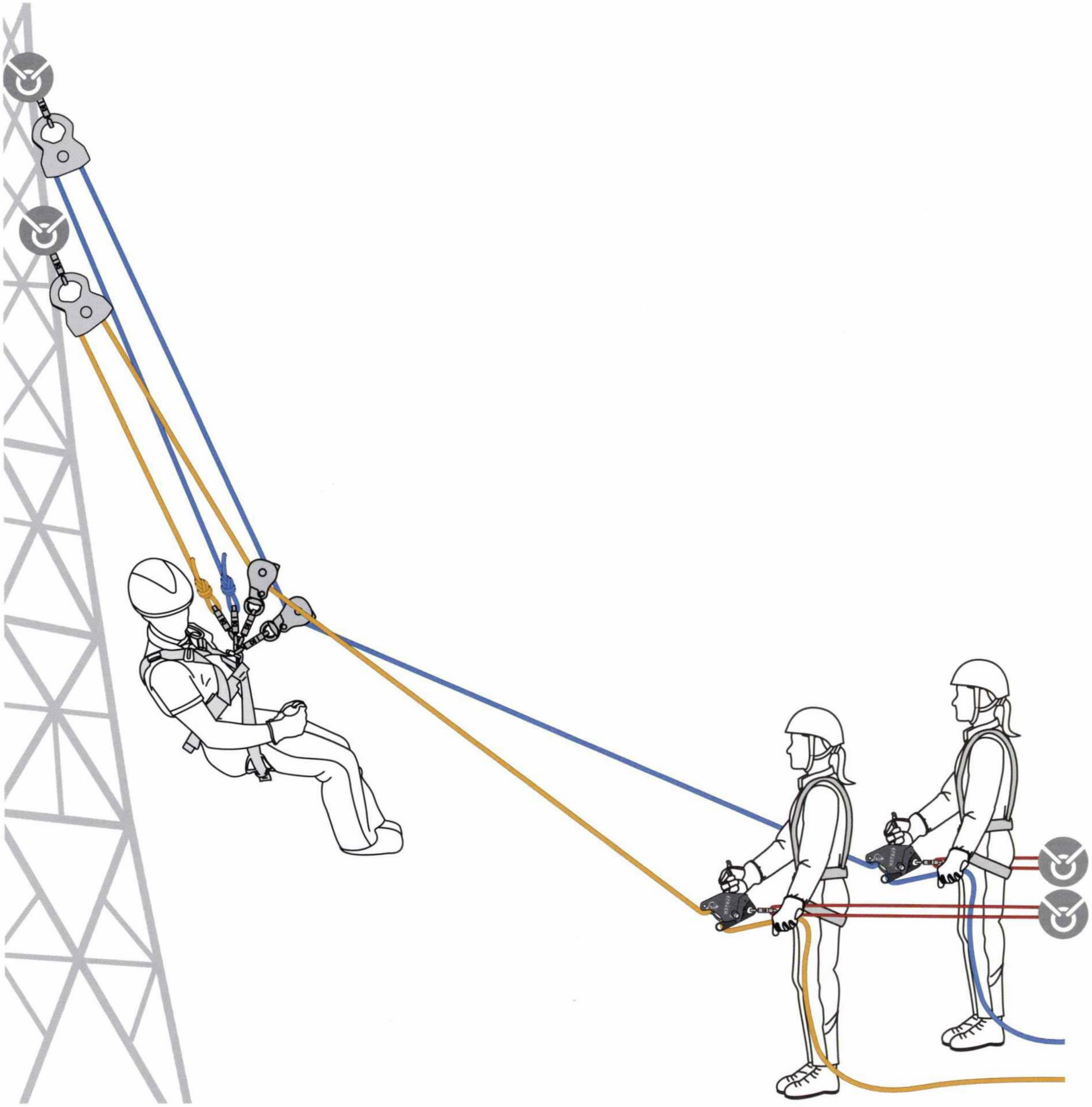


Figure 28-5: Skate Block System

the guide line. The control lines serve the secondary function of guiding the load away from the structure.

Rigging the Skate Block System

The Skate Block system is also very labor efficient. With the proper equipment, one person can operate a twin-tension Skate Block lowering system from ground level. This makes it ideal for small crews working on communications or power transmission towers.

The Skate Block may be constructed using the three common rope rescue systems. A traditional loaded main/slack belay, a single loaded main line with a travelling automatic belay, or as a twin-tension system. The advantages to the twin-tension systems have already been detailed earlier in this manual, so are not repeated here.

The system consists of the rope going from the subject (or litter) to a change-of-direction pulley above the subject. The rope then descends to the descent control device located at the anchor on the ground. The anchors are placed away from the structure to achieve the desired clearance.

The "skate block" is a second pulley mounted on the descending rope and then attached to the subject or litter. As the lowering begins, this pulley will cause the subject to track along the section of the rope that descends to the lowering device and anchor. The effect is to pull the subject away from the structure, guiding the subject towards the anchors.

The lower anchoring position is important in that it should not be immediately below the load. Too close and it will not assist with keeping the load away from the structure preventing entanglement. Yet it cannot be too far away because the more horizontal the lines become the more difficult it is to operate, and eventually, it won't work at all. The rule of thumb is 15-30 degrees, depending upon the distance to be lowered.

For a twin tension-system, the second rope is a mirror image of the first. Both lines connect to the subject and route separate "skate blocks" attached to the load. A second lowering device and anchor should be used.

Traveling Belay

For a travelling belay system, a rope is secured to the structure above the departure point and is routed through an automatic belay device, such as an ASAP, that is connected to the subject being lowered. A slack belay system could be a second rope attached to the subject, then through a belay device anchored and operated from above, or through a change of direction pulley to a manual belay device below.

If two CLUTCHES are used as lowering devices, a single rescuer can effectively control both lines. This requires both anchors to be close enough that the operator's hand can hold both of the CLUTCH handles. The easiest way to do that is to connect both CLUTCHES to the same anchor plate.

Skate Block Operation

It is best to connect both lines to the subject at the same point. In other words, both lines connect to the front of the harness or top of the litter. While it might appear to be safer, do not connect one line to the waist attachment and one to the dorsal. If you do that both ropes must be perfectly synchronized and moving at the same speed or it will be very uncomfortable for the subject because they will rock back and forth. That same theory applies to the position of the change-of-direction pulleys above the subject. They need to be reasonably close together.

If the system will be used for raising the subject, a change of direction would be installed, and a hauling system constructed at ground level. If the subject is being raised and the hauling system needs to be built at the upper level, a Skate Block will not work; you would need a Guiding Line or a traditional system with either an attendant or control line to maneuver the patient.

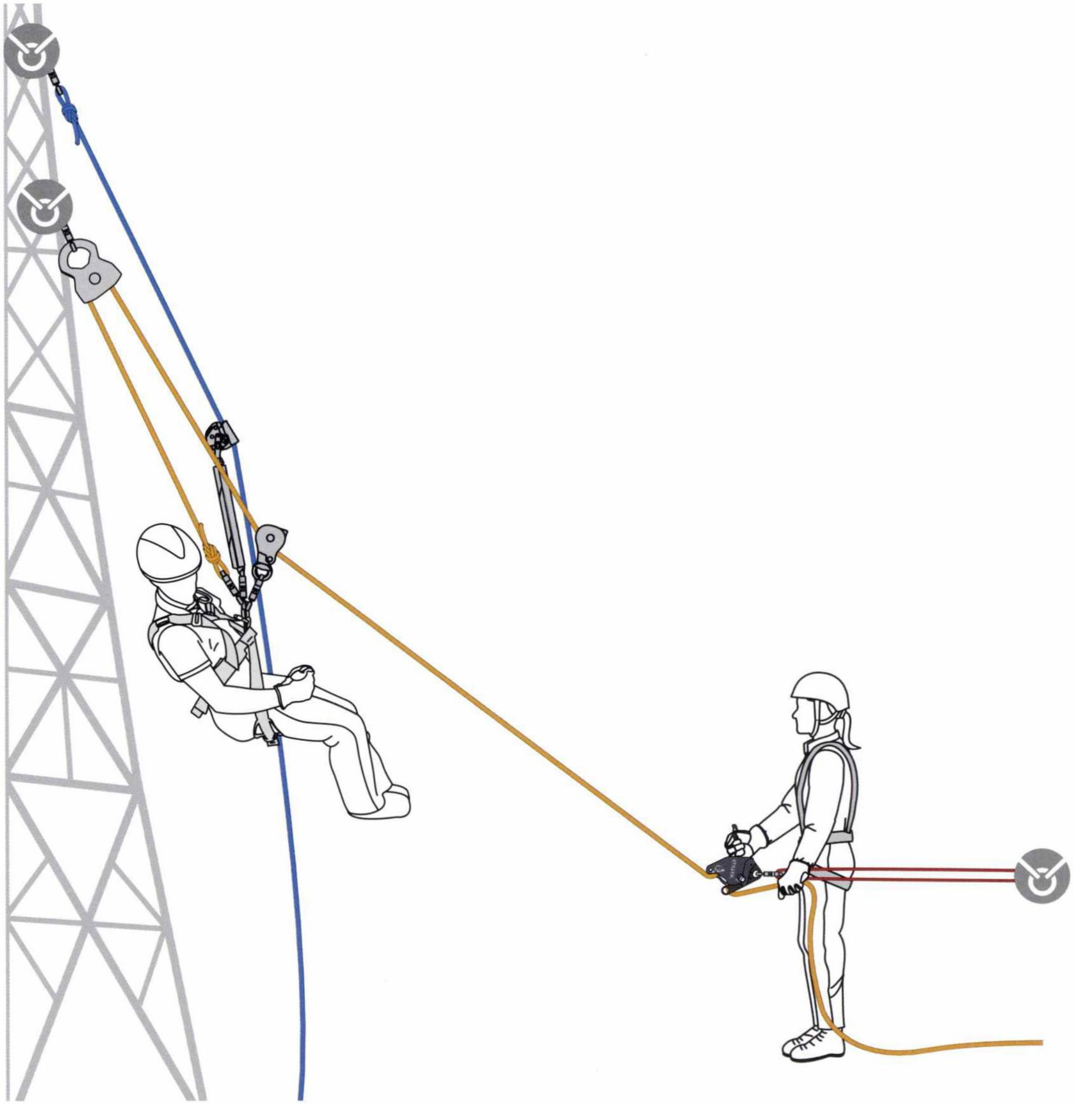


Figure 28-6: Skate Block System with a back-up device belay

Notes

PART
06
Rescue Techniques

CHAPTER
29
High Lines

LEGEND: Anchor Grip Load

TERMINAL LEARNING OBJECTIVE

The student will construct and operate a reeving high line.

ENABLING LEARNING OBJECTIVES

1. Describe system safety factors, critical angles, key components and force multipliers in high line systems
2. Construct and operate a reeving high line to perform a mid-span lower and raise
3. Move an occupied litter with an attendant from one elevated location to the other over an obstacle

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.3.5 | 5.3.6

High lines, sometimes called telphers or tyroleans, are rope systems suspended between two points that are used to move people or equipment between those two points. High lines can be horizontal, where the two endpoints are close to the same elevation, or sloping, where the end points are at different elevations.

High lines can be used to cross a steep canyon or gorge, a rapidly flowing river or to suspend a load over brushy or rocky terrain that would be dangerous or time-consuming to move a litter through. Yet many rescue teams discount the usefulness of high lines. If they are not well versed in the technique, it will take longer to set up. Teams that have taken the effort to master high-line rigging actually find it saves time on many rescues.

Another reason rescue teams shy away from high lines is the potential to overload the equipment and anchors with the possibility of a system failure. This is a very real concern, but one that, like the time restraints of set-up, can be alleviated by training. In the appropriate situations the benefits of a high line can far outweigh the drawbacks.

There are two basic types of high lines. The Kootenay high line is a tensioned track line that supports the load on pulleys or carabiners. The load can be lowered in mid-span by releasing the tension on the track line. A reeving high line keeps the tension on the track line and then lowers the load in mid-span by the use of pulleys and secondary ropes.

COMPONENTS OF A HIGH LINE

Track Line – The track line crosses the span and supports the load on the high line system. Low-stretch ropes should be used for all high lines. When rigged and tensioned properly, a single rope can safely support a rescue load within an acceptable SSSF. Two ropes can be used to reduce the sag of the track line without increasing the tension of the system by dividing the load between them. The second rope also backs up the first and adds to the overall safety of the system. Both lines must be tensioned at the same time with equalizing systems. In some cases, even additional track lines have been used to support heavier loads.

Static Anchor – The fixed end of the track line is usually referred to as the static anchor. A high-strength tie-off should be used to attach the track line to the static anchor to maintain maximum rope strength. If the anchor is not conducive to a high-strength tie-off, a large diameter pulley, such as a CMC's Kootenay Ultra Pulley or Petzl's KOOTENAY Knot-Passing Pulley, can be used. Anchor the pulley securely, taking into account the higher load it may have to hold. Lock the sheave from turning and then tie the track line to the pulley with a high-strength tie-off.

Tensioning Anchor – The tensioning anchor is the side of the high line where the tensioning system is located. Generally this side will require additional space to set up and operate a mechanical advantage system and room for a haul team to work.

Track Pulley – The track pulley, or carriage, supports the load traveling on the track line. It should be large enough so that the side plates will

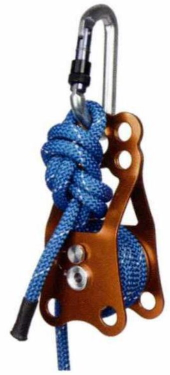


Figure 29-1: High-Strength Tie-Off to Kootenay Pulley

not drag on the track line. If the high line has two track lines, a wide pulley, such as the CMC Kootenay Ultra Pulley or a Petzl KOOTENAY Knot-Passing Pulley, will be needed. The extra carabiner holes on these large pulleys provide attachment points for the control lines, making these pulleys a popular choice even for single-line high lines.

Tensioning System – The system used to apply tension to the track line is called the tensioning system. It can be built using the track line rope or a piggyback system using another rope. A piggyback tensioning system should be connected to the track line using tandem Prusik hitches. The hitches grip the rope without compromising its strength, and if the system is overloaded, the hitches will slip before the rope breaks.

Control Lines – Are the ropes that run from each side of the load to the anchors on either side of the span. Prusik hitches are used to attach the control lines to the track pulley to maintain rope strength (see Figure 29-2). If separate ropes are used for the control lines, then using different colors will make operating the high line easier.

The control lines operate as both lowering and raising systems depending on the direction the load is moving and where it is on the track line. Since they also act as belay lines in case of a track line failure, the control lines should have tandem Prusik belay systems, CLUTCHES, or MPDs on both anchors and the slack should be kept out of the lines at all times. Even when properly managed, tests have shown that the load can drop up to 20% of the span before the belay catches it. Check the clearance of the track line over the ground or other obstacles to determine if the load is truly belayed.

Festoons – To keep the control lines from sagging, place a festoon about every 10 yd (9 m) on the control line. Use a length of web or cord and attach it to the control line with a girth hitch. Use a carabiner to attach the festoon to the track line so that it will slide along the line as the carriage moves. Stack the festoons on the track line between the anchor and the carriage and deploy them as the carriage moves across (see Figure 29-3).

Messenger Line – A *messenger line* is a small diameter cord that is thrown or shot across the span and is used to pull other lines across. Its small size allows it to be thrown or shot further than the heavier, larger diameter ropes used for track lines. The messenger line can also be used to determine which anchors will align the track line over the subject or where to place a high directional, if one is needed, to transition an edge. For long distances a Pilot Line can be used to pull the messenger line across the span.

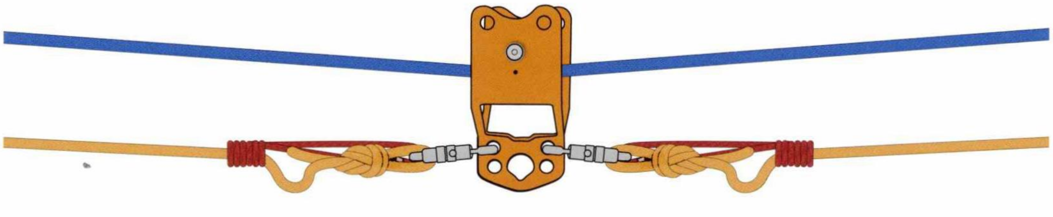


Figure 29-2: Control Lines Connected to Carriage with Prusik hitches

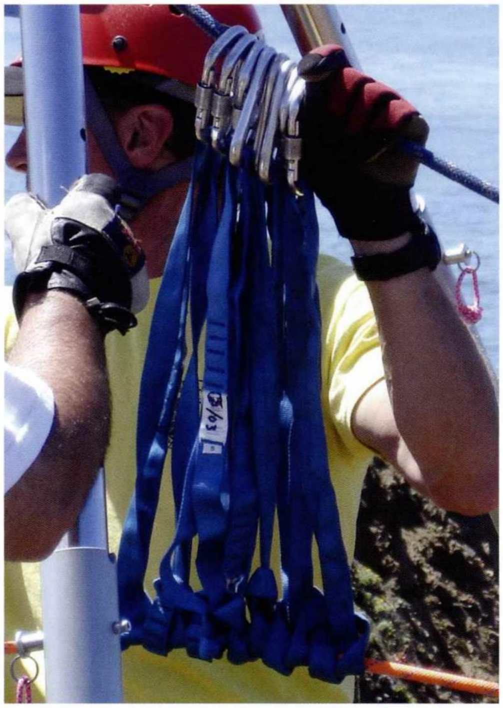


Figure 29-3: Festoons on control lines ready for deployment.

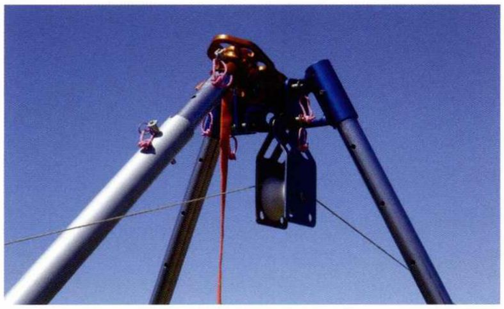


Figure 29-4: Messenger line running through a carriage on a high directional.

The messenger line should be attached to the far anchor. It will then be used to pull the track line across. A rescuer on the near side holds tension on the messenger line to keep it from sagging into water or trees below (see Figure 29-4).

A messenger line that is twice as long as the span can be used to move additional lines or equipment back and forth across the span. This allows the messenger line to be pulled back to the start without letting go on the other side.

Pilot Cord – This is a small (1 to 2 mm) cord sent across a span and then used to pull a heavier messenger line across.

Set-Up Considerations

Constructing a high line usually requires having rescue personnel on either side of the span to tie the anchors. In some cases, access by the rescuers to the other side is not possible, but the subject of the rescue or other non-trained persons may be there. If suitable anchor points are available, such as large trees, they could be told how to tie a high-strength tie-off or a tensionless hitch for the static anchor.

During the initial crossing, it may not be possible to provide a control line from the far side, thus allowing a belay from one side only. A risk/benefit analysis can determine if a high line without a complete belay is the best choice for crossing or if some other method should be used. The first rescuer across can pull a control line and complete the belay when they reach the far side.

High-line anchors should be elevated as high as possible to allow sufficient clearance where the load must cross the edge of the span. If necessary, the track line can be run through a large diameter pulley that is elevated and then the line is tied off at a lower level anchor. The latter may require building an A-frame, which must be set up before the system can be tensioned. Remember that the track line and control lines must be close enough to each other for the festoons to reach and that someone must be able to manage those.

FORCES ON THE HIGH LINE

Limiting the tension on high lines is necessary to stay within an acceptable SSSF. The wider the angle in the track line that is formed by the track pulley, the more the force on the anchors is multiplied. At 175°, the force on the anchors is 11 times the load hanging at the center. As the angle approaches 180°, the force at each anchor approaches infinity (see Figure 29-5).

Incorporating load cells or other force measurement devices into the system is the only way to determine the exact forces being placed on the anchors and other components. Once the high line is operational, movement of the load can result in force variations at the anchors of several hundred pounds. With the CMC Enforcer, it is much easier to place a dynamometer into the system for accurate measurement of the forces.

Incorporating Prusik hitches into the system provides a backup should the system be over loaded. Compact, portable load cells such as the Enforcer are a more certain method of managing the load.

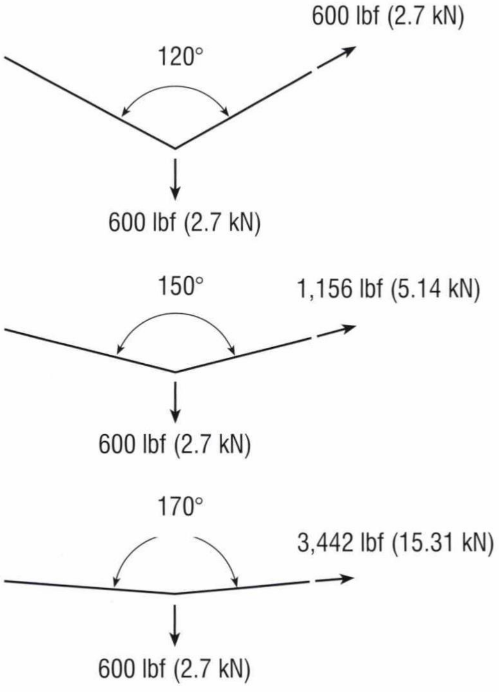


Figure 29-5: Force on Anchors

HIGH-LINE TENSIONING

Determining the tension in a high line by estimating the sag is not a particularly precise method when performed in the field. A good view of the high line may be difficult to obtain, the angle of sag is hard to estimate and even the width of the span may be a rough guess based on how much rope is left over. The following procedure for tensioning high lines has been verified in CMC School classes using our field portable load cell, which allows us to accurately measure the force at the anchor under various configurations.

Using the 10:1 SSSF we try to apply to all systems, a maximum force of 900 lbf (4 kN) can be placed on a NFPA G-rated rope static kernmantle rope with a MBS of 8,992 lbf (40 kN). As the load moves along a high line, tension increases until it reaches the maximum at center span. It then decreases as the load moves toward the far end. By tensioning the high line before the load is applied, there is the risk of overtensioning the system. Using a progressive tensioning system that increases tension up to a predetermined maximum during the operation of a high-line system can reduce this potential.

Testing has shown that by using a multiplication factor (number of people pulling times the mechanical advantage of the tensioning system) when the load is at center span, the 10:1 SSSF can be maintained. When using NFPA G-rated track lines, the multiplication factor is 18. When using NFPA T-rated rope (with a MBS of 6,744 lbf [30 kN]), a factor of 12 when the load is at center span will keep the system within the 10:1 SSSF.

Rule of 18

The rule of 18 provides a limit on the force used to tension a high line. It is based on the number of persons in the haul team, the mechanical advantage used with the load at center span and no knots in the rope.

For NFPA General use life safety rope:

# of persons in haul team x mechanical advantage ≤ 18

Examples:

2:1 M/A – maximum of 9-person haul team	2 m/a x 9 = 18
3:1 M/A – maximum of 6-person haul team	3 m/a x 6 = 18
6:1 M/A – maximum of 3-person haul team	6 m/a x 3 = 18

For NFPA Technical use life safety rope:

# of persons in haul team x mechanical advantage ≤ 12

Examples:

2:1 M/A – maximum of 6-person haul team	2 m/a x 6 = 12
3:1 M/A – maximum of 4-person haul team	3 m/a x 4 = 12
6:1 M/A – maximum of 2-person haul team	6 m/a x 2 = 12

Using a mechanical advantage system that divides evenly into both 18 and 12 is a logical choice as a tensioning system. For example, we use a 6:1 M/A system. After the high line has been rigged, pretension the system by having one person pull on a 2:1 or 3:1 M/A tensioning system. If more tension is needed as the load moves out toward center span, have one person increase tension by pulling on the 6:1 M/A. If still more tension is needed, increase to two people pulling on the 6:1 M/A. When the load is at center span, if more tension is needed, a third person could be added.

If more elevation is needed, the load can be shared on a second high line. Both high lines can be tensioned equally with a single system by adding another moving pulley in series with the compound 6:1 as shown in Figure 29-6. The forces were calculated using pulleys with a 95% efficiency rating

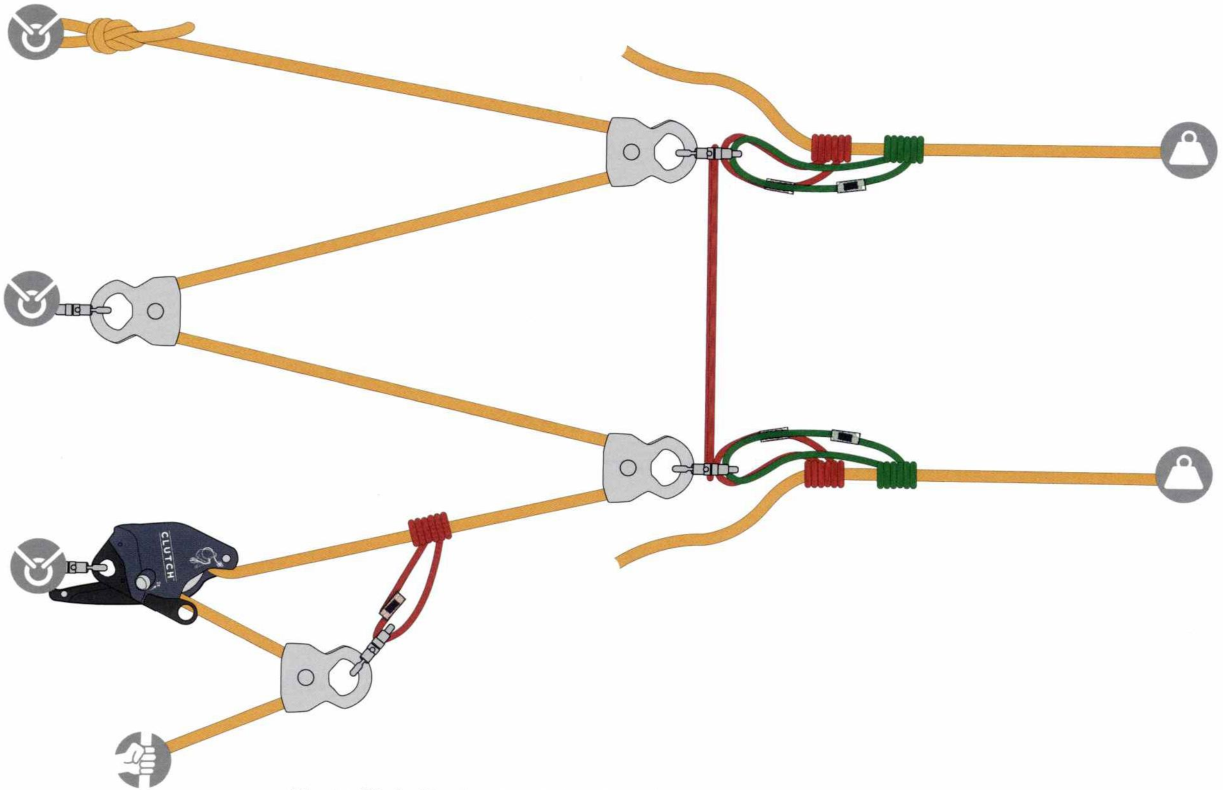


Figure 29-6: Mechanical Advantage System for Equal Tension on Two Track Lines

and an input force of 60 lbf (0.27 kN) per person. This input force was the average force found during testing that a person puts on a haul line before they ask for help or decide to increase the mechanical advantage.

Caution: It is not the maximum force the haul team could apply to the rope. By using this progressive tensioning system and tensioning as the load moves across the high line, the weight of the load does not have to be considered to calculate the force. A heavier load will not be lifted as high as a lighter load with the same maximum force.

OPERATING A HIGH LINE

Once the high line is set up and pre-tensioned, the load is attached to the track pulley. The load is moved out by releasing (lowering) the near control line and tensioning the far control line. If the track line needs to be tensioned to allow the load to clear the edge, remember to detension it once the load is clear. Set a festoon every 10 yards or so as the load moves across. On the far side, the festoons need to be released and managed as the load moves across. If more tension is needed as the load nears the center, use progressive tensioning up to the maximum when the load is at center span. At center span, the far side control line will need to begin to haul to bring the load up to the edge, while the near control line will keep out slack but not apply so much tension that it would make it harder for the far side to move the load.

REEVING HIGH LINE

One of the advantages of a high line is the ability to access difficult locations. A reeving high line allows a rescuer to be positioned over the subject, lowered and then retrieved with the

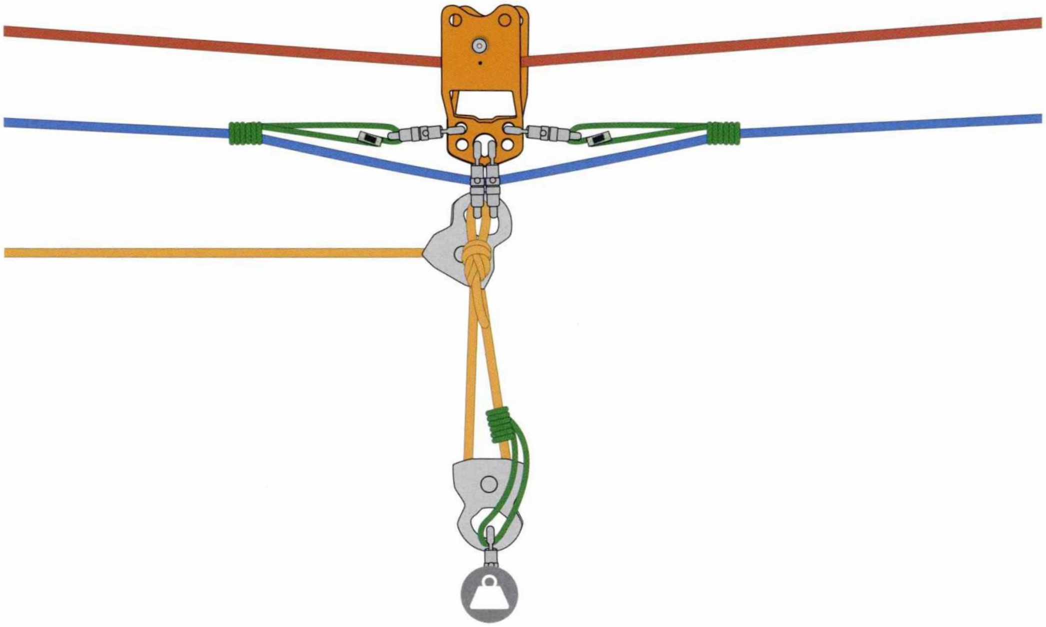


Figure 29-7: Norwegian Reeve High Line

subject. We find that the Norwegian reeve system works well in most situations (see Figure 29-7).

The control lines hold the track pulley in position while the reeving system lowers and raises the load. The Prusik hitch on the fixed rope side of the reeving system supports the load. To lower, raise slightly on the reeving system to allow the rescuer to release the Prusik hitch, then lower into position. The rescuer sets the Prusik hitch when positioned. If the track line was tensioned more than the pretension force, remember to detension before picking up any additional load. Lift the load off the ground and then re-tension as necessary using the rule of 18 (for NFPA G-rated rope). When the load is raised, the pulley minds the Prusik hitch, allowing the rescuer to manage the patient.

The reeving line has a 2:1 built into the system. If additional mechanical advantage is needed, a 3:1 can be added to increase to a 6:1. Once the load is back at the track pulley, a second connection from the pulley can be added to back up the Prusik hitch supporting the load. The control lines then move the load across to one side.

PART
06
Rescue Techniques

CHAPTER
30
High Anchors & Directionals

LEGEND: Anchor Grip Load

TERMINAL LEARNING OBJECTIVE

The student will assemble and use different manufactured and improvised devices to achieve a high anchor point or high directional.

ENABLING LEARNING OBJECTIVES

1. Describe the common high anchor and high directional devices and explain where they are most commonly used for rope rescues
2. Construct and operate a ladder gin and ladder "A" frame system
3. Construct an improvised "A" frame high directional

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.2.13 | 5.2.14 | 5.2.19 | 5.2.21 | 5.2.22 | 5.2.23

A high anchor point can make the rope rescue system easier to use. Placing a change-of-direction pulley at a high anchor point makes transferring the load to the rope a smooth transition instead of the sometimes backbreaking and dangerous job it can be, particularly when the system goes over an edge or is lowered into a hole. In some situations a suitable anchor may already exist, such as a structural support for a roof, floor, pipe or machinery. It may be possible to position the lifting point of a crane above the opening. If you are called to perform a rescue and see one of these devices in place, consider it as an option for the rescue. Important points are the integrity of the device, its height and lifting mechanism. Assuming it is not the cause of the rescue, in other words it has not collapsed or been structurally damaged, you could use it, which would save both time and effort.

Use a pre-existing natural anchor which could be the limb of a tree or another structural member for an anchor point located above you. A high anchor point may be essential if you are trying to access a subject located in a tree, on an access ladder or on a tower.

In other cases it may require the use of a manufactured or improvised high directional that you bring to the rescue, such as the Arizona Vortex, a rescue or industrial tripod/quadpod, ground ladders or timbers to construct an A-frame.

TRIPODS

The tripod is the most commonly used high anchor point. It is portable and relatively easy to set up even by one person. Commercial tripods are constructed with telescoping legs that allows them to be collapsed for storage and transport yet to be tall enough to be usable for a rescue. Most industrial tripods are available in two sizes with maximum working heights of 7 ft (2.1 m) to 9 ft (2.7 m). Our experience is that construction and maintenance crews tend to choose the shorter height because it is smaller and lighter (and less expensive). Remember, their use is for ambulatory workers. For rescue, where there is the possibility that you will need to remove a subject on a backboard or in a litter, a taller tripod (9 ft [2.7 m] or even higher) is recommended. If there is an issue with overhead clearance, for instance inside a building with a low roof, the tripod can always be shortened by retracting the legs.

Tripods are free standing and by adjusting the leg extension can be used on inclined surfaces such as a cone roof tank. Most tripods come with some means to secure the legs from splaying outward. If a chain, rope or cable is supplied with the tripod, then it must be properly attached to the legs or the tripod may not withstand its rated working load. The legs should be angled outward as far as possible for maximum stability. If leg latches are provided, they should be engaged.

For a vertical lift, a tripod should not have to be guyed to remain stable. There are two key points to remember for tripod stability: 1) any system for lifting the load must hang centered within the legs of the tripod and 2) all loads must be kept within the legs. An easy way to remember the latter rule is to keep the load within the chain or hobble system that independently connects the legs. During a rescue operation, it is common for the subject to be hauled from the space and have a well-meaning rescuer pull them away from the opening and tip the tripod over. The feet of the tripod can be staked, tied down to pickets or a similar anchor if the surface allows but that should not be necessary with proper rigging.

Tripods are strongest when their legs are fully retracted and are required by OSHA to have a minimum working strength of 310 lb (141 kg). That rating is for fall protection purposes and in most cases the breaking strength is several times that, even with the legs fully extended, which is your indicator that the tripod is meant to be loaded with a single person. In an industrial rescue, it would be a very rare occurrence where both a subject and rescuer would need to be lifted at the same time and that situation should be avoided.

Quadpods are similar to tripods but as the name implies they have four legs instead of three. They are more stable than a tripod due to the additional leg but for the same reason are also heavier. They seem to be harder to adjust on anything other than a level surface but the other rules for tripods—securing the legs, centering the load—still apply.

ARIZONA VORTEX

The Arizona Vortex is a specially designed tripod more correctly described as an easel A-frame. It has three support legs that come apart for moving and storage. The legs are stored as separate pieces and must be assembled for use. That can be an advantage because the pieces are smaller and lighter but set-up time and complexity is increased. It can be set up in many different configurations, so in some cases, as when a vertical opening is against a wall, it can be used where a tripod would not fit. For more information or to download the user's manual, visit www.cmcrescue.com.

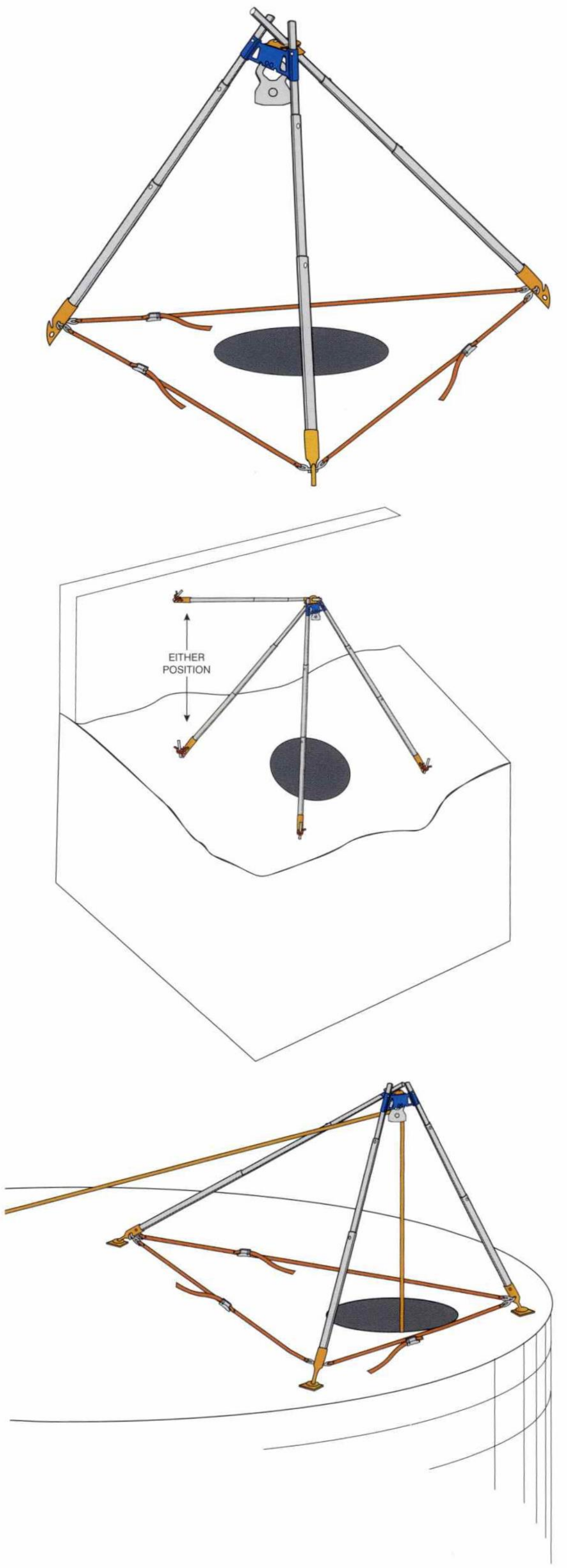


Figure 30-1: With a wide variety of leg length and angle adjustment, the Arizona Vortex can provide a high anchor point in the most challenging locations.

DAVIT ARMS

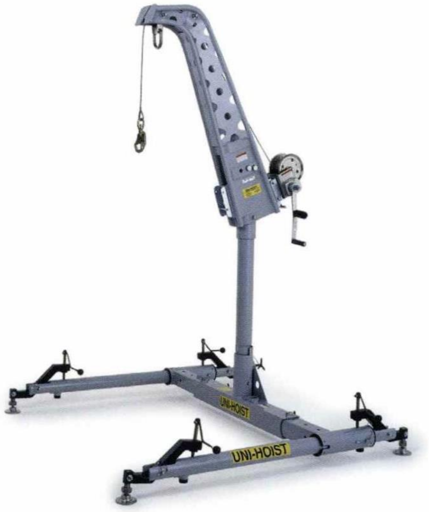


Figure 30-2: Davit Arm

Davit arms are fixed or portable crane-like devices that project over the edge of a building or the opening to a confined space. They are often installed in industrial environments where entries are made on a regular basis or where the height or small work area at the top of a vessel makes the use of a tripod difficult or impossible. Portable davits have an H- or V-base that has adjusting jack screws to level it. A separate mast and arm assembly is then installed in the base with the tip over the opening.

They are usually not as high as tripods, which can make them difficult for rescues, but most have the advantage of pivoting away from over the opening. Another davit arrangement is to have a fixed base socket at each confined space and a single arm assembly that can be carried between them depending upon where the work is taking place. This arrangement is common at wastewater treatment plants, food processing and paint manufacturing plants or other locations where there are multiple tanks in close proximity that are entered regularly for cleaning.

INDUSTRIAL CRANES AND FIRE DEPARTMENT AERIAL APPARATUS

Bridge cranes, mobile cranes, fire department aerial apparatus and other similar devices can be useful as high anchor points or high directionals in confined space and rope rescue. They can be positioned over the opening to the space or above the edge of a cliff, allowing enough height for an easier edge transition. Once the crane boom or aerial ladder is positioned as close as possible to the rescue and the ropes and pulleys are attached, it should be locked out. At no time should a crane's winches, hydraulics or other lifting or raising mechanics be used for the rescue. Such equipment is designed for lifting things much heavier than a single-person load, and the risk that the rescuer or subject could become caught on something and dismembered before the operator would know and have time to react is too great.

We regularly get questions about the use of aerial fire apparatus for various rescue applications. Upon researching the subject there seems to be mixed opinions among the various apparatus manufacturers as to what is approved and what is not. So it is best to know the limitations of your particular apparatus and the manufacturer's recommendations before you use it as a high directional.

As is the rule when operating the apparatus in the traditional firefighting mode, the less the extension and the steeper the climbing angle, the stronger the platform. The ladder acts as a giant lever that is trying to overturn the apparatus, hence the reason for the steep angle and short extension. That also keeps the forces more in line with the ladder beams and reduces the pressure on the hydraulic rams that lift and position the ladder.

Some apparatus have eyes on the underside of the platform or on the ladder tip. The general rule seems to be to use anchor straps or webbing through each, creating a multipoint anchor system and centering the load between them. A centered load will reduce torquing or twisting of the ladder. In the case of a straight ladder a similar technique should be used. By placing anchor straps around each beam that will share and center the load. The rope from the pulley should be routed directly under the center of the ladder to a change of direction on the vehicle. The raising and lowering system can then be constructed on the ground. Some even suggest running the rope on the walking surface of the ladder to a change-of-direction pulley at the turntable.

The use of belay lines with an aerial as a high directional is another topic for discussion. All loads, whenever possible, should be belayed. Using an aerial as a high point is no exception. It is generally recommended that the belay line be independent of the aerial. Even the best belayer will have some slack in the belay rope. This slack plus rope elongation during a main line failure, translates into force. Aerial ladders are not designed to handle shock loads.

When using a crane with adequate load capacity, in confined space situations we recommend attaching a 4:1 pulley system directly to the hook. As long as the crane boom is near maximum elevation and boom tip height is minimized, the resultant of the crane's cable will be close to the boom. The issue to watch for here is the jerky hauling motion so often associated with 4:1 hauling systems. This jerking motion produces shock loads that transmit to the rams of the crane.

The use of the platform/ladder to receive a patient in a litter from a high point and then lower them to the ground is also a point of discussion. Our experience is that it sounds easier than it really is, and in most cases a well-trained rope team can complete the rescue just as quickly and with a greater level of safety. Many manufactures prohibit placing a litter on the rails of the platform without having a way to secure it. Loading the patient would require a belay line on the litter and in many cases access would not allow the vehicle to get into position. Be very careful if you intend to use your platform aerial for this application and practice the technique before you need to use it in an emergency.

Some basic points to remember when using aerials as high directionals:

- First and foremost check with the manufacturer of your aerial apparatus. They are aware of design uses and limitations
- Minimize shock loading by using more haulers. Using only a few haulers tends to result in jerky movements
- Avoid tying directional anchors to the outriggers
- Consult load charts to determine the maximum tip force
- Avoid running the belay line through the high directional. Any main line event that causes the belay to activate may result in a catastrophic shock load

- Maximize the climbing angle. This ensures your resultant will be close to the ladder and is loading the aerial in compression
- Never move the aerial when a load is attached to the tip
- Maintain your resultant as close as possible to the climbing angle of the aerial

GIN POLES

Using only one leg, the Gin Pole is the lightest, most portable of the high anchor points. It also requires the least space as only one footprint is needed. Since it is inherently unstable in all directions, it requires the most guy lines and thus the most time to set up. The pole should be angled so the resultant force is as much in line with the pole's length as possible. This drives the foot into the ground for greater stability and puts the least load on the guy lines.

Because of the need for multiple guy lines to stabilize a Gin Pole, the top of the pole needs connection points. This can be very slow to rig if using a 4 x 4 or other improvised pole. The gold head piece on the leg of the Arizona Vortex provides quick guy line attachment points. Even more efficient is the AZORP for maximum flexibility in rigging.

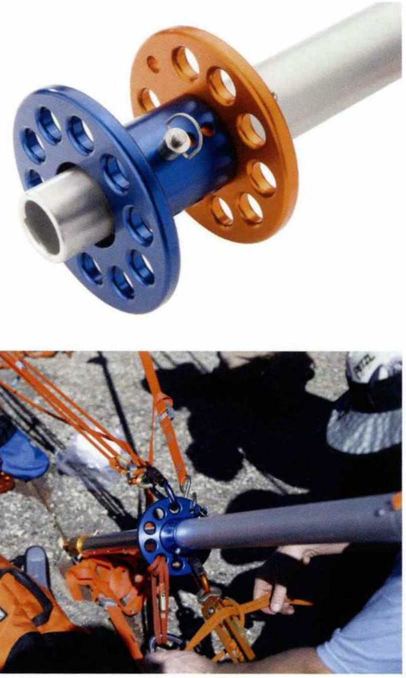


Figure 30-3: AZORP

The Arizona Omni Rigging Pod (AZORP)

The Arizona Omni Rigging Pod (AZORP) is a companion piece to the Arizona Vortex. Stability for a gin pole requires three or four guy lines and the AZORP provides multiple attachment points at all angles. The two sections can be used together or split apart and used individually. The AZORP could also be attached to a leg of the Arizona Vortex to provide lower rigging points than from the head pieces. For example: this would allow a lower attachment point for belaying the Arizona Vortex to a back anchor.

Caution needs to be used to make sure tensioning a mid-point connection on a Arizona Vortex leg does not lift the leg and destabilizing the Arizona Vortex.

BELAYING

No matter which type of raising and lowering system or high point anchor you are using, a separate rope belay is recommended. The belay will serve as a safety in case of system or anchor failure and for that reason should be routed at ground level and not through the high anchor point. If the belay line were routed through a pulley at the top of a tripod and the tripod tipped over, the load would drop twice the height of the tripod before the belay would catch. That fall distance would severely compromise the belay and in many cases the person would hit bottom before the belay could catch the load. An additional reason for using a tandem Prusik belay, CLUTCH or MPD at ground level is that it can easily be converted to a 3:1 M/A system. Using a belay of this type satisfies two regulations. It provides fall protection and at the same time provides a method for non-entry rescue should an entrant be incapacitated while not on the cable winch or other lifting device.

Belay Options with an Artificial High Directional

When using an Artificial High Directional for an over-the-edge transition, the belay line can be rigged in three different locations. Each has an advantage and disadvantage.

High – running the belay line through a pulley at the apex of the AHD eases the edge transition by the stretcher team. This would also be the set up for a Twin-Tension system. The concern would be a topple or collapse of the AHD, creating slack in both lines, resulting in a potentially long fall and high shock load.

Low – running the belay on the ground eliminates the concern about the AHD toppling. The concern in this configuration is having a mainline or AHD failure before the load clears the edge, also resulting in a potentially long fall and high shock load.

AZTEK – running the belay line through the AZTEK or a similar system allows the belay height to be adjusted. The belay can be near the top for the edge transition, then lowered after. By holding the belay line just above the ground, edge protection is not required. When transitioning back up over the edge, the AZTEK has sufficient M/A to move the belay line up.

RESULTANT FORCES ON HIGH ANCHOR POINTS

The type of device or systems used to raise and lower the load and how it is rigged will determine how much force is applied to the high anchor point. If a winch is attached to the leg of the tripod or the mast of a davit, the force is applied in compression to all three tripod legs or davit arm and then vertically down from the point the rope or cable leaves the change-of-direction pulley (see Figure 30-4).

As stated earlier, rope systems can create different problems where resultant forces are concerned. If the high anchor point is used with a change-of-direction pulley, the resultant force

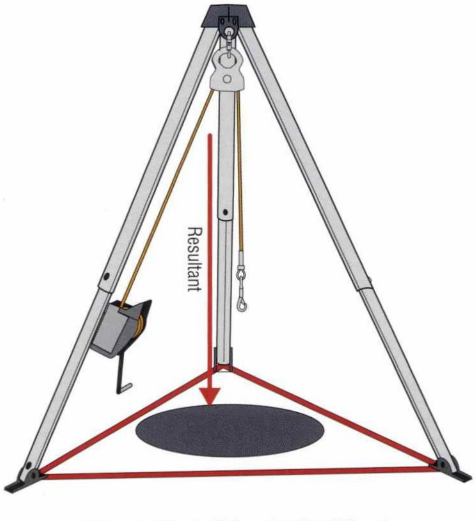


Figure 30-4: Tripod with Winch

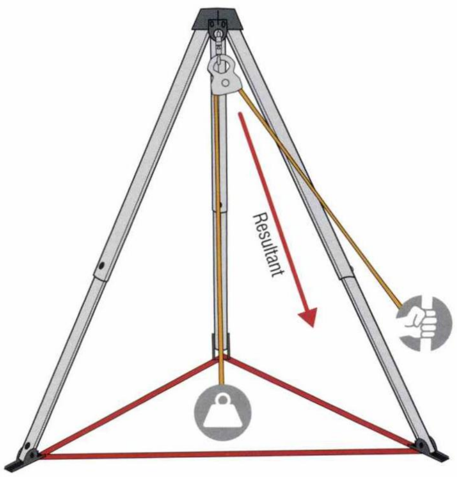


Figure 30-5: Tripod with Resultant Outside the Footprint

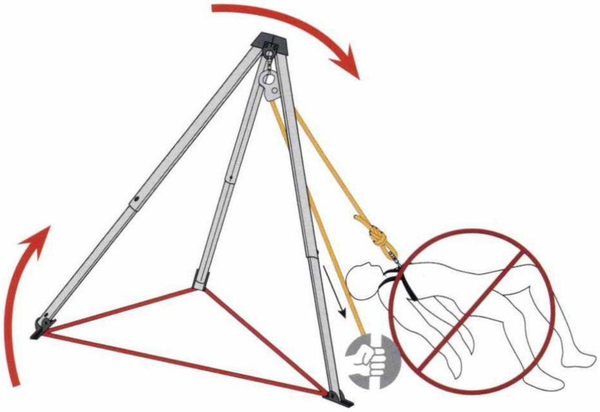


Figure 30-6: Tripod with Subject Pulled Away from Opening

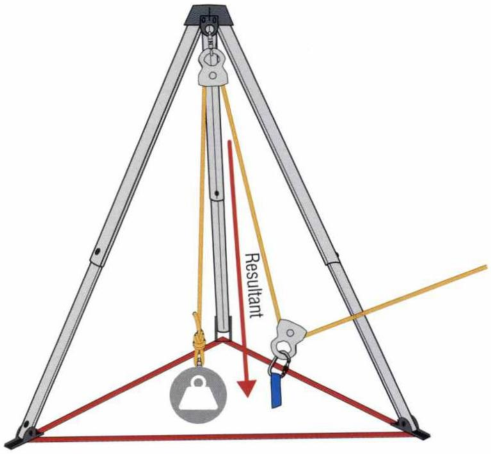


Figure 30-7: Low Directional to Keep the Resultant Force Inside the Footprint

will bisect the angle formed between the load line and the haul line as they enter and leave the pulley. Since the load line should always be vertical, rigging the haul line to keep the resultant as close to vertical as possible will keep a free-standing high anchor point stable.

Tripods are designed to be loaded vertically with the resultant force as close to the center of the three legs as possible so that they share the load equally. As the resultant is moved away from center, the load on the leg, or legs, nearest the resultant is increased and the load on the opposite leg is decreased, which reduces the overall strength and stability of the tripod. If the resultant force falls outside the footprint (triangle formed by the three feet or chain around the base,) stability will be lost and the tripod will tip over (see Figure 30-5).

Even with several warnings, we commonly see students attempt to pull the subject or rescuer away from the opening after they have been raised out of the space which, if they are allowed to do so, will topple the tripod (see Figure 30-6).

Equally important to the angle of the resultant force is the amount of force different rigging configurations apply to the high anchor point and other change-of-direction anchors. The actual force is a function of the angle created by the ropes through the pulley. Several examples are shown to the left.

In Figure 30-7, the angle of the rope through the high directional pulley is 15°. If the load on the end of the rope is 300 lbf (1.33 kN), the force on the high anchor point would be 600 lbf (2.67 kN). The angle of the rope through the low directional pulley is 90°, so the force on the lower anchor is 422 lbf (1.88 kN). And remember, this is a generalization. Due to friction in the pulley the load will be higher.

Even the commonly used simple 4:1 pulley system will place a higher force on the high point anchor than the load being lifted. Using the T-method to analyze the forces shows that the high point anchor sees 1.25 times the load when hauling. That equates to 375 lbf (1.65 kN) on the anchor when lifting a 300 lbf (1.33 kN) load.

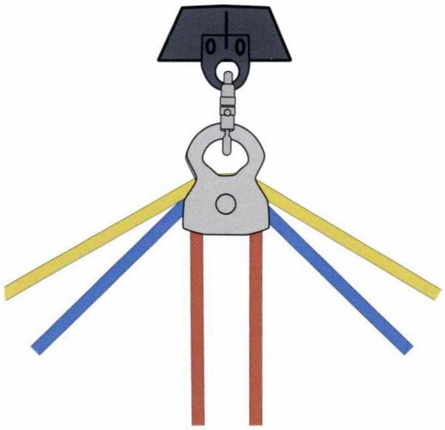
The examples in this chapter show just some of the available tripods, rope and ladder systems available.

We have attempted to explain the key points common to most systems but you should read, understand and follow the manufacturer's instructions for your particular brand of equipment.

IMPROVISED A-FRAME

Components

Poles – An A-frame requires two strong poles, pipes or pieces of lumber that will support the intended loads. Building, placing and using the A-frame properly will put most of the forces down the length of the poles in a compression mode. Metal poles work well and can sometimes be found at the site of an urban or industrial rescue. Wilderness rescuers, if they are equipped with a saw (and an understanding forest supervisor), can cut poles from appropriately sized trees. Construction lumber may also be used. Four-by-four inch timbers without large knots or splits will hold most loads encountered on rescues.



Interior Angle		Resultant Force
120° (Yellow Line)	=	1 times the load
90° (Blue Line)	=	1.41 times the load
0° (Red Line)	=	2 times the load

Figure 30-8: Load on Tripod for Various Rope Angles

The length of the poles is determined by the availability of materials and the size of the area the A-frame must fit. Indoor locations may have height limits. Wilderness and industrial locations can have cramped locations that leave little room to spread the legs of the A-frame wide enough for good balance.

The longer the pole, the more chance there is of leverage compromising the structure and resulting in a failure. Twelve- to 14-foot poles will assure that the load will be located high enough to clear most edges. Eight- to 10-foot poles will work in many situations. If the poles are too long, locate the lashing closer to the base. A ledger pole lashed across the base of the A makes a triangle, which adds to the stability but is not essential.

Spar Lashings – Lashings are used to bind two or more poles together. They are useful for improvising rescue anchor points during rescues. The two types of lashings used in building A-frames are the round lashing and square lashing. The names are descriptive of the turns they make and how they appear when finished. The round lashing is used to construct the A-frame. The square lashing is used to attach the ledger pole across the bottom.

Round Lashing– A round lashing is most often used to bind two poles together to form the A-frame. To tie this lashing:

Step 1: Place the poles on the ground parallel to each other with a 2 in (51 mm) spacer between them. The spacer can be a small block of wood or any object that will help hold the poles apart. Placing a brick, rock or block of wood under this end of the poles makes tying the round lashing easier.

Step 2: Start by tying a clove hitch on one pole about 2 ft (0.6 m) back from the elevated end.

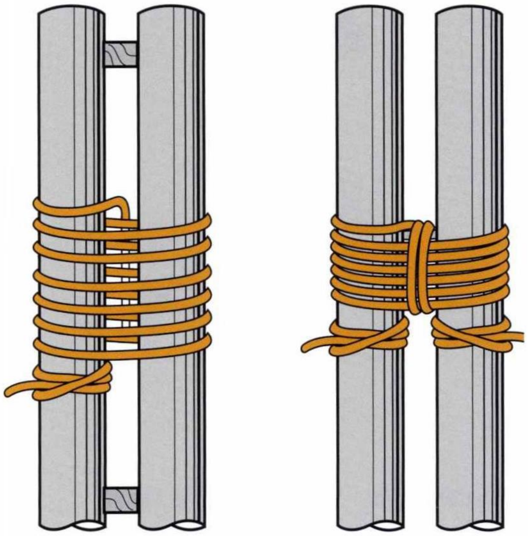


Figure 30-9: Round Lashing

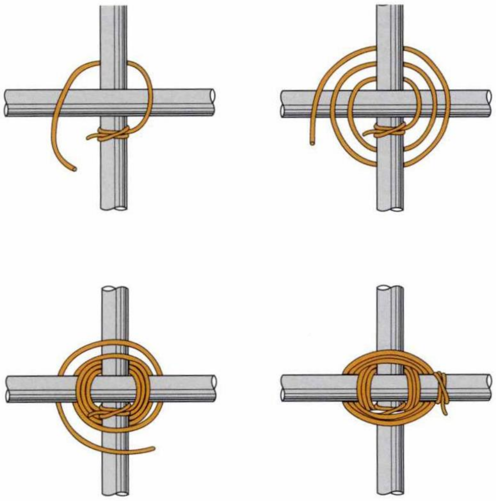


Figure 30-10: Square Lashing

Step 3: Make six close turns around both poles traveling upward toward the elevated end of the poles. Remove the spacer.

Step 4: Make two or more frapping turns between the two poles and around the six turns of rope.

Step 5: Secure the end with another clove hitch around the pole below the lashing, opposite the starting clove hitch.

Square Lashing – The square lashing is used to hold two poles together at near right angles, such as attaching the ledger pole. To tie this lashing:

Step 1: Place the ledger pole at approximately a right angle to the leg poles. Tie a clove hitch around one leg pole below the ledger pole.

Step 2: Wrap the rope up over the ledger pole and around behind the leg pole, back over the top and around the front of the ledger and around behind the leg pole.

Step 3: Repeat this circuit three more times.

Step 4: Make four frapping turns around the lashing and between the poles.

Step 5: Finish with a clove hitch around the the ledger pole.

Step 6: Follow the same procedure to lash the ledger pole to the other leg.

Guy Lines – A guy line is used to support the A-frame to prevent it from falling. At least two guy lines are required: one to the front and one to the rear. Make the front guy line adjustable by running the line through a Prusik hitch attached to the anchor.

The rear guy line is the tensioning guy line. A mechanical advantage system on the rear guy line pulls the A-frame tight against the front guy line. In situations where the A-frame is being used to pull the load over an edge or to support a high line, it is better to have three guy lines, one to the rear for tensioning and two toward the front by the edge. Spread the front guy lines apart to provide clearance for the litter.

Constructing the A-Frame

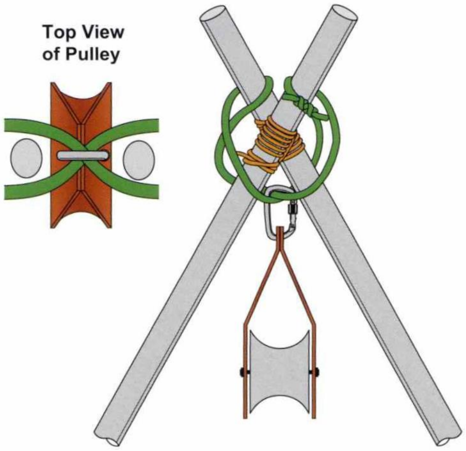


Figure 30-11: Attaching a Double Sling to the A-Frame.

The following steps can be used to build an A-frame:

Step 1: Place two poles parallel to each other on the ground and in line with the guy line. The instructions assume one rope for the guy line but two separate ropes can also be used.

Step 2: Locate and set anchors for the guy lines.

Step 3: Use a round lashing to bind the two poles together.

Step 4: Pull the base ends of the poles apart a distance about one-third the height of the poles measured from the lashing to the base. At the base of the poles, tie a piece of rope or webbing between them, so they cannot spread further apart, or attach a ledger pole.

Step 5: Tie a double sling over the top of the A-frame (see Figure 30-11). Be sure to have the sling bearing against the poles and not entirely on the lashing.

Step 6: Rig the main line through its pulley and connect the pulley to the sling. On a tall A-frame rig the main line and connect the pulley before raising the A-frame or the sling may be too high to reach.

Step 7: Attach the guy line to the top of the A-frame. Tie the center of the guy line onto the legs with clove hitches directly above the lashing. The guy line should be attached to the pole furthest from its anchor. This will hold the poles together when loaded.

Step 8: Lift the top of the A-Frame and walk it up by hand until the tensioning guy line can be used to lift the top into place. Be sure to foot the base of each leg so it does not slip.

Step 9: Position the A-frame so the top of the A is near the edge. In most cases it is not necessary for the top to extend out over the edge to gain adequate edge clearance. Edge rollers or other edge protection should be used to protect the rope if there is any edge contact. The high anchor point will allow the litter to clear the edge.

For a high line, the angles between the A-frame and the track line (angles A and B) should be equal (see Figure 30-12). When using the A-frame for a vertical mechanical advantage system, the angle between the tensioning guy line and the A-frame (angle A) and angle between the mechanical advantage system and the A-frame (angle B) should be equal (Figure 30-13).

Foot or block and brace the base of the poles by digging holes, driving stakes into the ground or otherwise securing the base of the poles. If the A-frame is set up on rock, tie the base of the poles to anchors below the edge.

Steps in Setting Up a High Directional

We often see in class and the real world, rescuers finding a good spot for the high directional then trying to make the rope stay there. The rope when it is tensioned will always load in a straight line between the anchors. If the high directional was not correctly oriented, loading the rope will tip the high directional over.

- Find the anchor points on both sides
- Send the pilot and messenger lines across the span
- Then determine where and what orientation to set the high directional

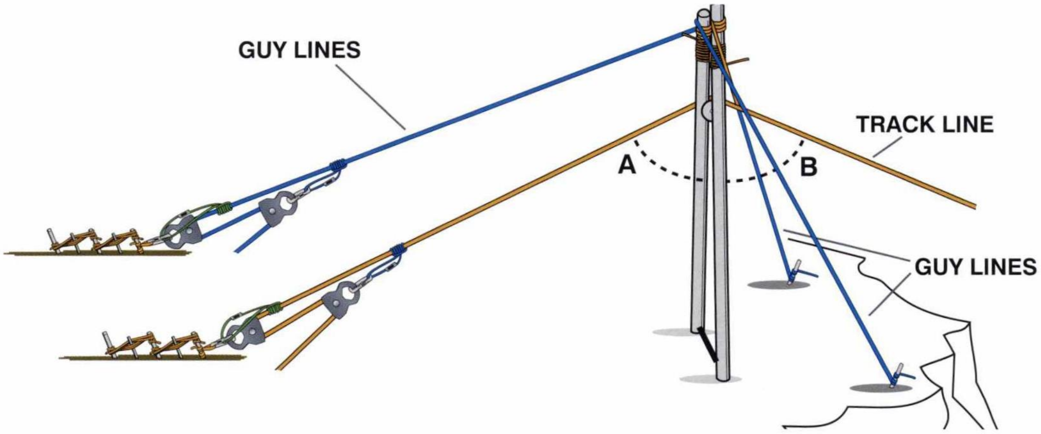


Figure 30-12: A-Frame Used With a High Line. Angles A and B Must Be Equal.

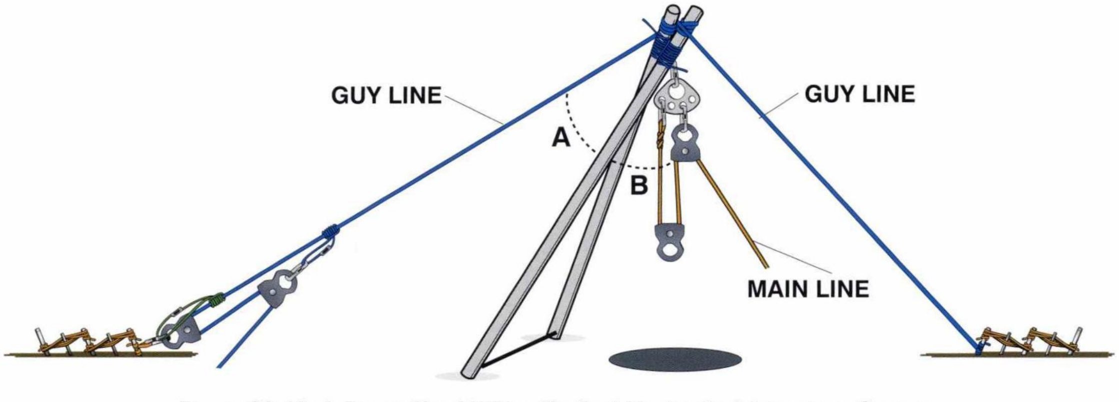


Figure 30-13: A-Frame Used With a Vertical Mechanical Advantage System.

PART
06
Rescue Techniques

CHAPTER
31
Ladder Rescue Systems

LEGEND: Anchor Grip Load

TERMINAL LEARNING OBJECTIVE

The student will demonstrate how to set up and operate ladder rescue systems.

ENABLING LEARNING OBJECTIVES

1. Demonstrate the set-up of a Ladder A Frame
2. Demonstrate the set-up of a Ladder Gin
3. Demonstrate the set-up of a Moving Ladder Slide
4. Demonstrate the set-up of a Ladder Slide
5. Demonstrate the set-up of an Exterior Leaning Ladder
6. Demonstrate the set-up of an Interior Leaning Ladder
7. Demonstrate the set-up of a Cantilever Ladder

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.2.5 | 5.2.13 | 5.2.16 | 5.2.23

Fire service or commercial Type 1A ladders may be rigged in a variety of ways to make a rope system evacuation more efficient. While normally associated with entry into a confined space or exiting structures, a ladder may make movement over a rough surface easier. Also, an open stairway is essentially a ladder, and some of the following techniques might work as well.

LADDER A FRAME

The Ladder A-Frame is constructed using two ladders at least 14 ft (4.3) in length. Ladders of unequal lengths will work. An extension ladder may be disassembled, and the two sections used. Roof ladders should be inverted so the hooks are down.

Place the ladder butts together, then spread slightly to allow the beams to be interlocked. The top rungs, or top rung and adjacent rung for different length ladders, are lashed together. Spread the butts approximately 45 degrees. Attach guy lines to the top and tension out to each side. Secure the ground ends by connecting them together to prevent spreading or anchor each ladder to the ground.

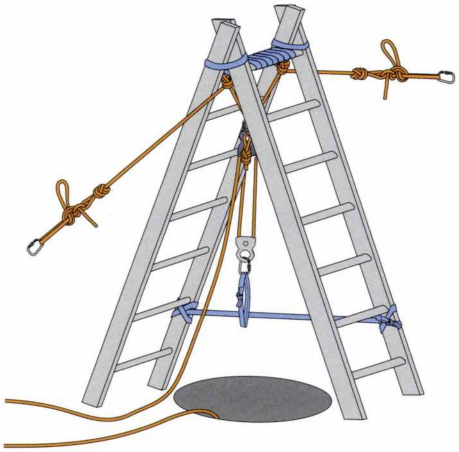


Figure 31-1: Ladder A-Frame with a Simple M/A System

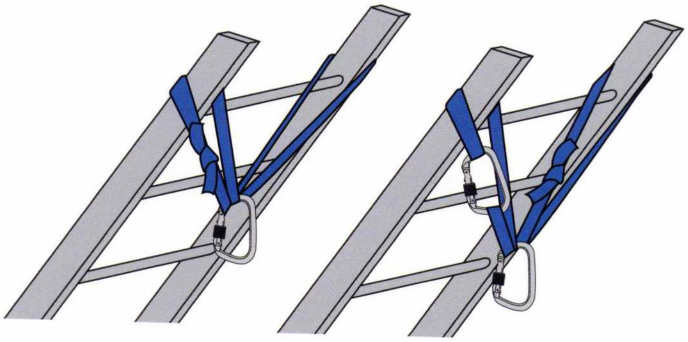


Figure 31-2: Simple ladder Sling (left), Pre-tied Ladder Sling (right)

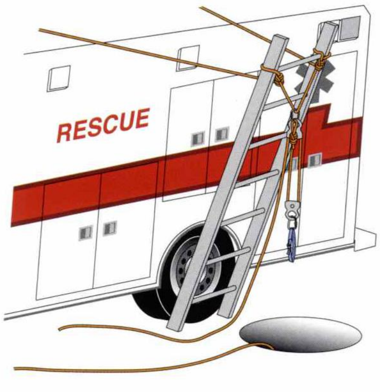


Figure 31-3: Ladder Gin Against Vehicle

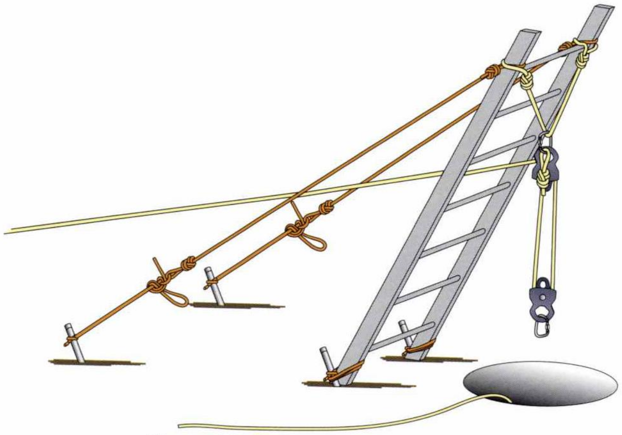


Figure 31-4: Open Field Ladder Gin

LADDER GIN

A single ladder can be rigged for access into a confined space or over a barrier such as on a roadside. The ladder is anchored from the top to points on a vehicle, to pickets, or to other terrain-based anchor points. The foot of the ladder should butt up against a solid object such as vehicle tire or curb. Otherwise, the foot should be lashed to pickets.

MOVING LADDER SLIDE

Lashing the litter to a ladder essentially lengthens the litter so that it can be moved over terrain that cannot be accessed. If the litter is being lowered over a parapet or other high edge, attach the litter at the bottom of the ladder. For transport over more level terrain, attach the litter towards the center of the ladder.

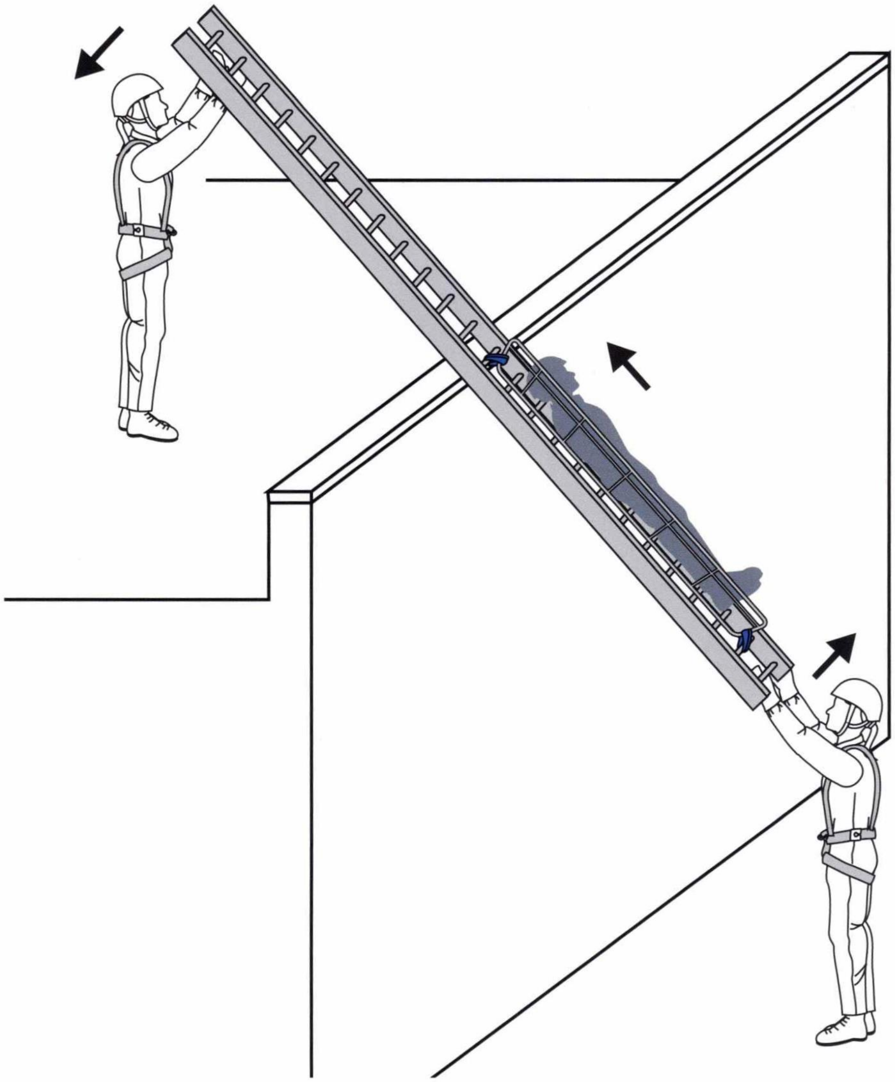


Figure 31-5: Moving Ladder Slide

LADDER SLIDE

A ladder may be used to turn a vertical evacuation into a low angle evacuation by leaning the ladder against the structure. The ladder is in a fixed position and the litter slides on the ladder. The ladder should be anchored at the top or at the foot to prevent any inadvertent shifting of its position.

Since tenders are not involved and the litter is sliding on the ladder, a lower mechanical advantage may be used for when raising. As with other evacuations, a Twin Tension or a Main/ Belay System should be used.

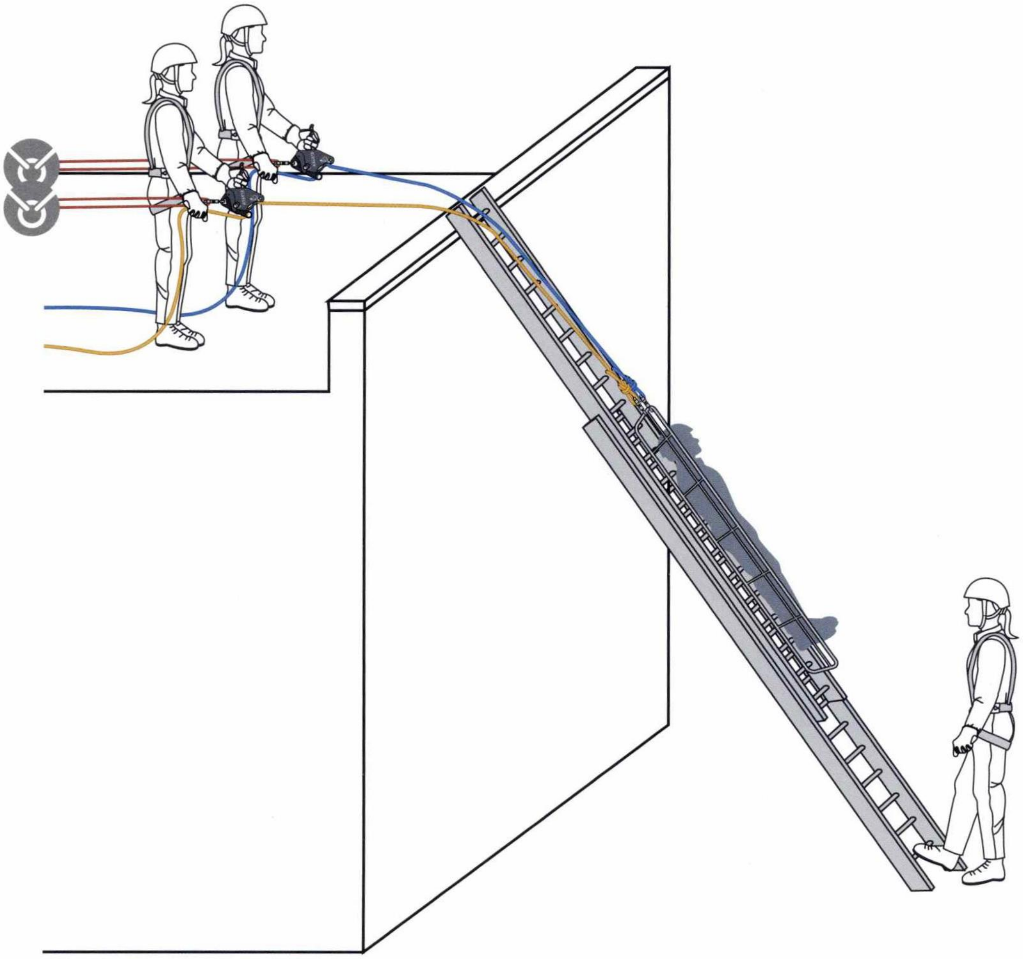


Figure 31-6: Ladder Slide- Lowering

EXTERIOR LEANING LADDER

The Exterior Leaning Ladder System quickly creates a high anchor point that permits evacuations from every floor below the high point of the ladder without repositioning. Position the ladder as high as possible. If the high anchor point cannot be reached from inside the structure, attach the change-of-direction pulleys and ropes before positioning the ladder.

Again, since no tenders are on the litter, the M/A or lowering system only needs to deal with the weight of the patient. As with other evacuations, a Twin Tension or a Main/Belay system should be used.

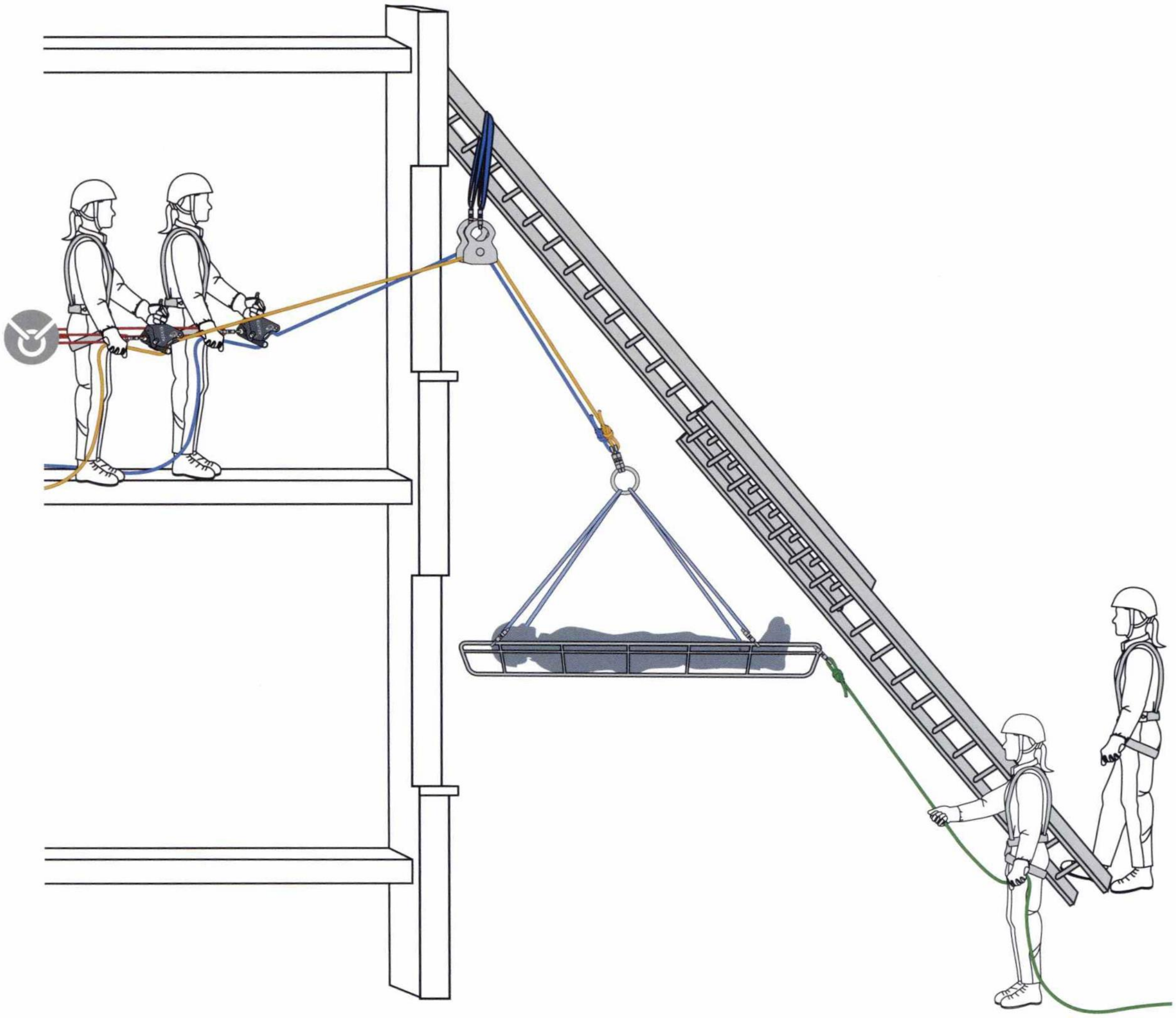


Figure 31-7: Exterior Leaning Ladder

INTERIOR LEANING LADDER

By bracing a ladder between the floor and the wall at ceiling height, an interior anchor point can be established. The rope is run through the ladder rungs for the friction needed to control a lowering. Positioning the ladder on a high floor provides access to all the lower floors below.

The California State Fire Marshal Rescue Systems 1 text recommends reeving the rope under the bottom rung, between the second and third rungs, back over to the bottom rung, again through the second and third rungs, then up to between the first and second rungs down from the top of the ladder. Position the rope next to the ladder beams to maximize rung strength.

It would be best to use a Main/Belay System for the Interior Leaning Ladder. The belay could be placed at a lower exit point, but always at or above the exit location of the litter.

CANTILEVER LADDER

The Cantilever Ladder rigging uses a ladder to extend an anchor point outside a window or over a parapet wall, providing access to windows or exits below the ladder level. The rope may be reeved through the ladder as in the Interior Leaning Ladder System.

Several considerations must be considered to make a Cantilever Ladder functional as well as stable. The rope descending from the ladder should be at the rung closest to the wall. A rescuer is used to counter-weight the ladder and at least seven rungs must be inside to offset the weight of the load being lowered. The rescuer used for the counterweight must remain in place until the evolution is completed and direction to move is received.

It would be best to use a Main/Belay system for the Cantilever Ladder. The belay could be placed at a lower exit point, but always at or above the exit location of the litter.

See the figures on the next two pages.

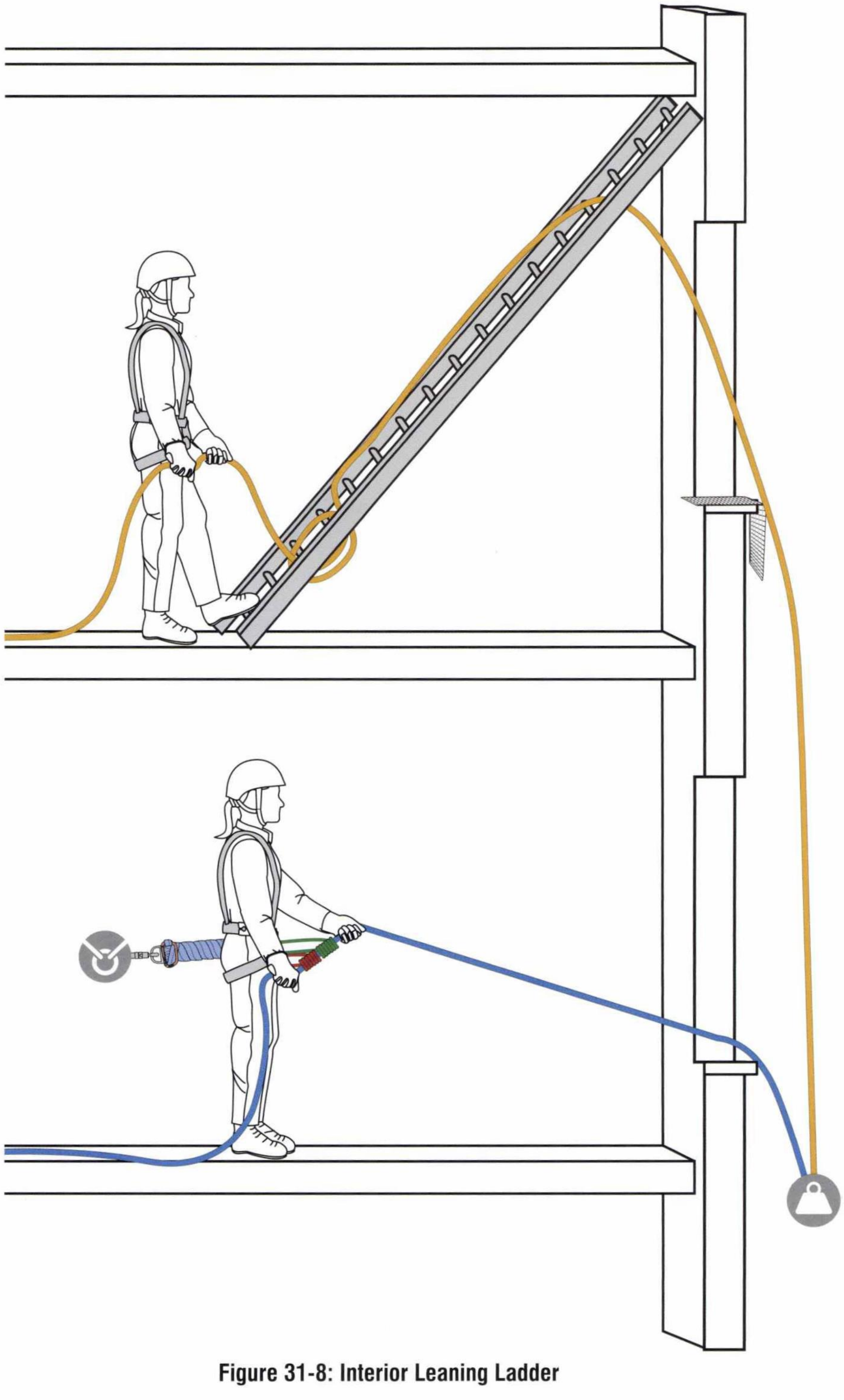


Figure 31-8: Interior Leaning Ladder

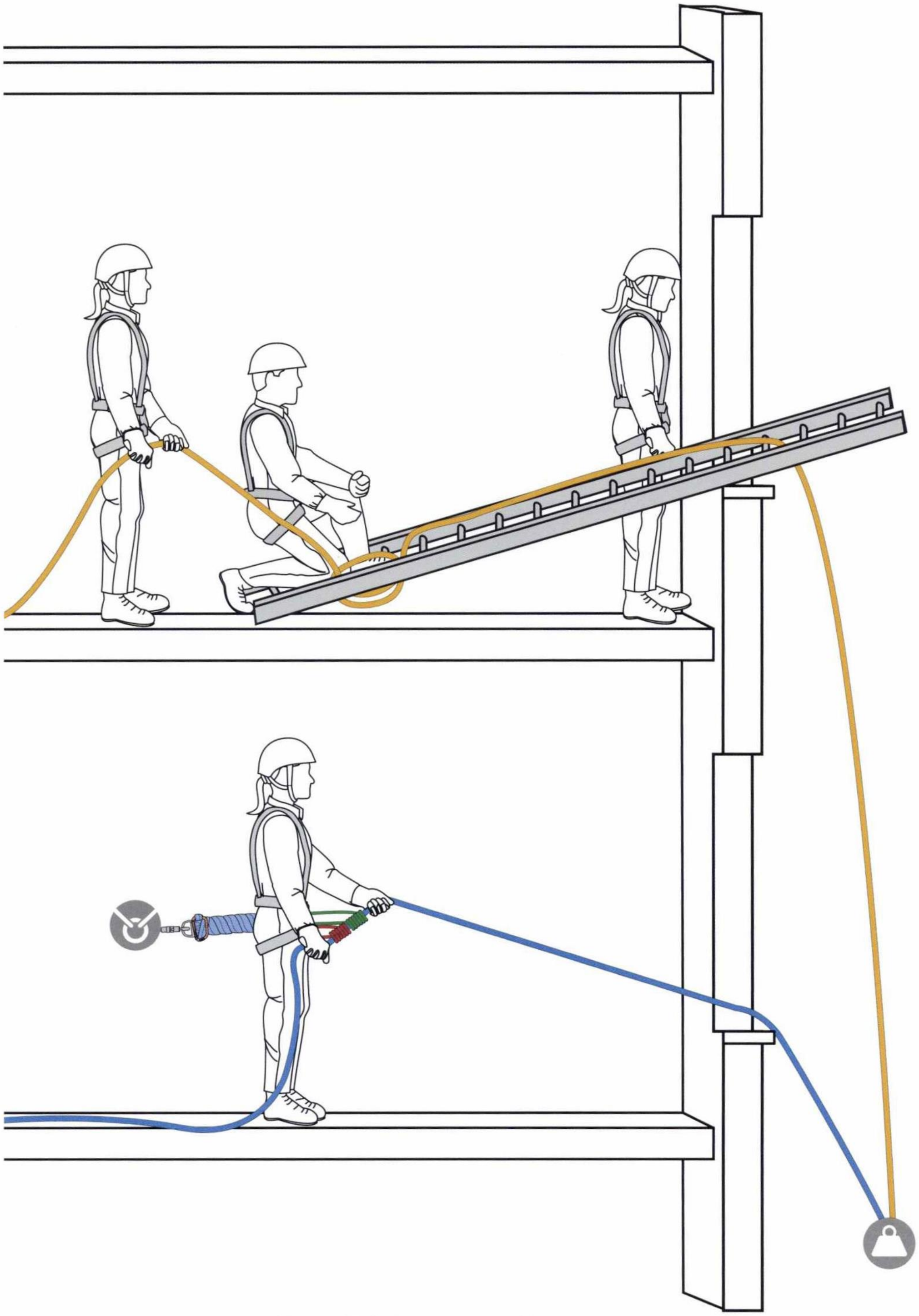


Figure 31-9: Cantilever Ladder

PART
07

Rescues

CHAPTER
32

Organization & Planning

LEGEND: Anchor Grip Load

TERMINAL LEARNING OBJECTIVE

The student will explain the Incident Command structure for a typical rope rescue and the commands used during the rescue operation.

ENABLING LEARNING OBJECTIVES

1. Describe the benefits of a rescue preplan for a rope rescue evolution
2. Describe the methods, both verbal and nonverbal that can be used for basic commands during a rope rescue operation
3. Describe how to recognize the need for technical rescue resources
4. Describe how to provide support at an operations or technical level incident

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.1.4 | 5.1.5 | 5.2.1

Rescue units come in a variety of types and sizes. There are full-time paid professionals employed by public safety agencies, industrial safety personnel and volunteers responding to wilderness incidents. A rope rescue team may be the rescue squad, the EMS responders or the technical rescue team. Sometimes the rope rescue team will be organized at the scene using firefighters, paramedics and law enforcement officers who have had training from their departments. Wherever they come from, the rescuers arriving on scene will rely on teamwork, equipment and their experience to solve the problem. Some of the discussion below may apply more to one type of unit than another, but you never know when an idea for improvement may be stimulated.

ORGANIZATION

Rescue cannot be done by committee. Before the action starts, your team must have a functional command structure to manage the approach to the problem. One key to success is to put the best man for each job in that position. Training sessions are the place to develop new skills and evaluate member's capabilities, not during rescues. On a rescue, the team is expected to give its very best.

An exception to this occurs when the Incident Commander can determine that time is no longer essential to the response, such as in a body recovery. This may provide the opportunity for the less experienced team members to get some real time experience. Could you gain operational experience with a stable, non-injured subject? That requires a judgment call, balancing training needs and legal liability. In the medical profession, interns build experience by treating the non-critical patients. On the other hand, if something goes wrong and you injure the subject, you may be in a difficult position explaining why you did not give your best effort.

It is important to accept that your team has limitations in what it can do. Very few teams have a high level of skill in all the various types of rescue work, plus the proper equipment and sufficient personnel. You have a responsibility to realistically evaluate your team's capabilities and to locate and evaluate the resources your team can draw upon from the surrounding area. Also, this process will let those resources know about your team. Someday that other agency may need your team, because the rescue they are responding to will need the skill, equipment or personnel that your team can supply.

If your team works regularly, or even just occasionally, with another department or agency, joint trainings should be held. This helps the management people to get their roles straight and lets the field people develop confidence in each other. Most important, good teamwork between agencies increases the level of safety for all involved.

THE RESCUE PREPLAN

Many volunteer teams do not have the management or command systems that exist in professional departments or the larger volunteer departments that operate like a paid department. Responding to fires, medical emergencies and rescues on a daily basis polishes the command system. For the less active team, we have found that too much time is often

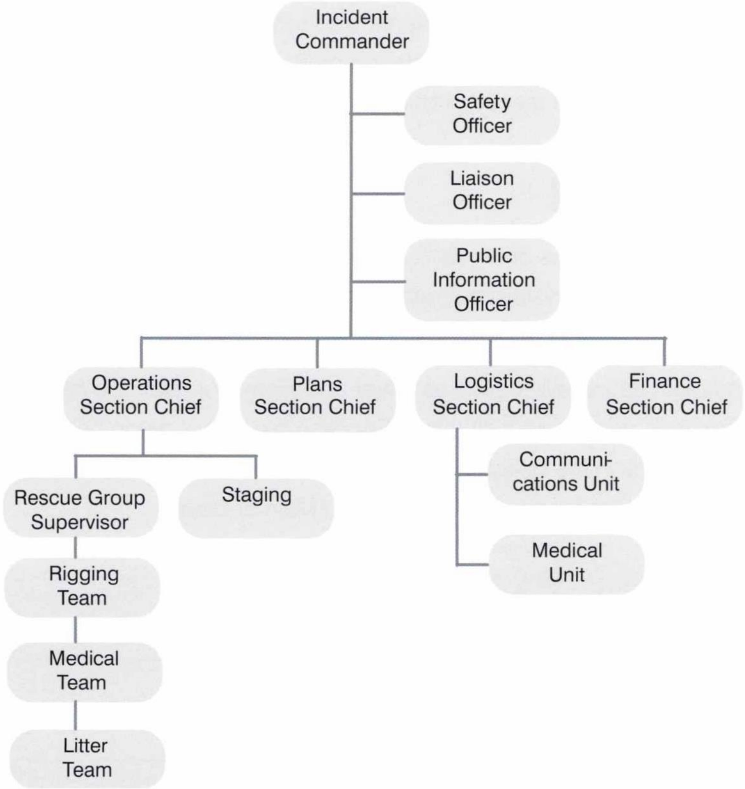

Incident Commander
Safety Officer
Liaison Officer
Public Information Officer
Operations Section Chief
Plans Section Chief
Logistics Section Chief
Finance Section Chief
Rescue Group Supervisor
Staging
Rigging Team
Medical Team
Litter Team
Communi- cations Unit
Medical Unit

Figure 32-1: Rope Rescue Incident Command System Chart

spent on the routine management work necessary to get the rescue started. If you are responding to a particular type of rescue regularly, analyze those responses and see how much time is taken just getting started. Look closely at the management decisions that you make each time you respond. How many of those can you make ahead of time? How many can be delegated ahead of time?

In the 1980s, a typical rescue team would arrive at their meeting location and discuss the initial plan for the rescue. Over the years, rescuers realized that on each rescue they would always access, stabilize and then transport the subject. With this in mind, teams were able to predetermine specific job positions and corresponding tasks. The resulting rescue preplan provided an organizational framework in which everyone knew what was expected at the start. As team members arrived at the station, the positions would be filled and the team would be on its way to the scene. As more information was received while traveling or upon arriving on scene, the plan was updated.

By staying close to the framework of the preplan, you maintain the flexibility to adapt to the particular response. When everyone knows their job and its expectations, then it is easy to add extra people as needed or, if necessary, have one person fill two positions. Also, the team leaders know how the initial part of the response should be developing, so less communication and discussion is required, yet the channels of communication remain open.

The Incident Command System (ICS) is the standard organizational structure for rescue responses as well as most emergency incidents. The rope rescue segment could be the entire incident or part of a larger incident. The rescue preplan provides the framework for the tactical plan to solve an incident's rope rescue problem.

COMMUNICATIONS

Effective team communication is an essential element of a rope rescue operation, particularly the coordination between the system operators and the tender (or litter team leader.) Whenever possible, place a team member in position to observe both the litter and the system.

Avoid commands that sound alike, such as *lower* and *slower* or *haul* and *halt*. Also, use commands rather than describing a situation. For example: "up rope on belay" or "up belay" rather than "there's slack in the belay line." In some situations, using rope color to describe which rope is being referred to may work better than Main or Belay.

System Setup/Maintenance Commands

By IC, Rescuer, Riggers – repeated amongst team members:

Command	Meaning
"Tension/Slack rope color"	Prep for action by checking readiness of all

Rappelling Commands

By Rescuer and Belay

Rescuer Command	Meaning	Belay Response	Meaning
"On rope"	Announcing connecting to ropes		
"On belay?"	Asking	"Belay on"	Belay ready
"Rappelling"	Announcing movement	"Belay on"	Confirming
"Tension" or "slack belay"	Request to tighten/loosen belay	"Tension" or "slack"	Repeat
"Down"	Rescuer at bottom	"Belay off"	Stop belay
"Off Rope"	Announcing disconnect from ropes		

System Evolution Commands

By IC and Rescuer – repeated amongst team

Command	Meaning
"Rescuer Ready" or "Raise/Lower Ready"	Prep for action by checking readiness of all
"Up/Down" or "Raise/Lower"	Move the system
"Slow/Fast" or "Slow-Slow/Fast-Fast"	Adjust the speed
"Reset" or "Knot Pass"	System stop while M/A is reset or a knot is passed
"Stop"	Stop system movement

Warning Commands

By ANY team member

Command	Meaning
"Stop or All Stop"	When a problem or danger is identified
"Rock"	Falling rock or anything falling
"Rope"	Rope being deployed

Anyone can give the command *stop* to cease all movement. The system should then be checked to determine why stopping was necessary and if any adjustments should be made.

We prefer to have the tender be the only person to give the command that starts movement: up rope or down rope. This assures that the people on the litter really are ready.

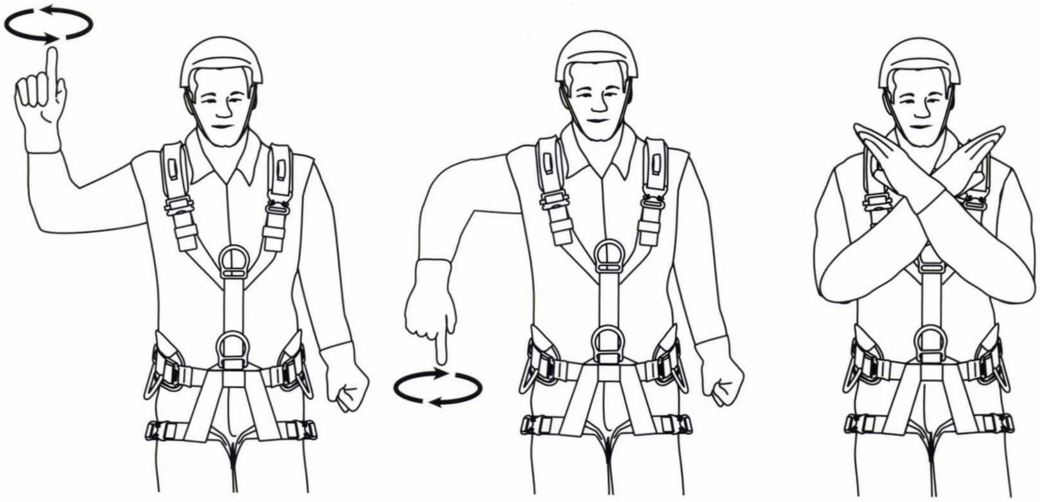
All other communications should be by the team leaders. Keep the tender advised when the system will be reset or a knot pass is coming so they know why they are stopping. The tender also should advise the haul team of any need to stop or when approaching steeper sections that will increase the load.

SUDRH Whistle Signal System

Stop	1 short whistle blast
Up	2 short whistle blasts
Down	3 short whistle blasts
Rope Free	4 short whistle blasts
Help	Continuous Blast

Whistle Commands – A simple whistle system makes an excellent backup to radio or voice communications, see ASTM F1768 ***Standard Guide for Using Whistle Signals during Rope Rescue Operations.***

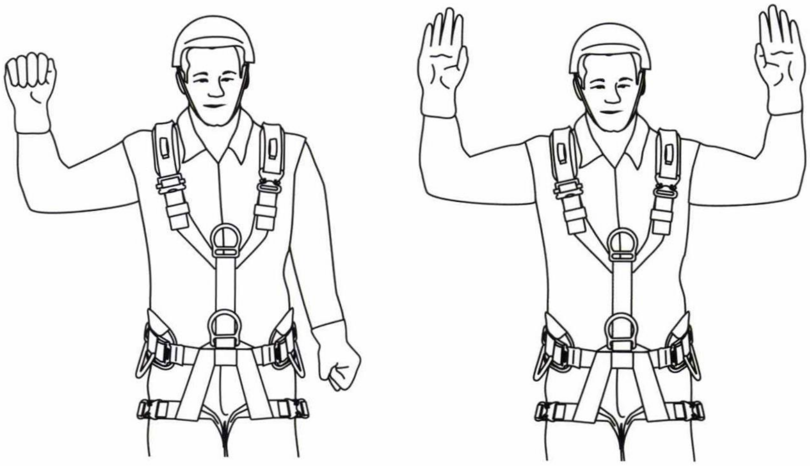
Hand Signals – Hand signals are very useful in high-noise environments, such as next to fast-moving water or a vehicle that has a generator running for lighting.



Raise Load

Lower Load

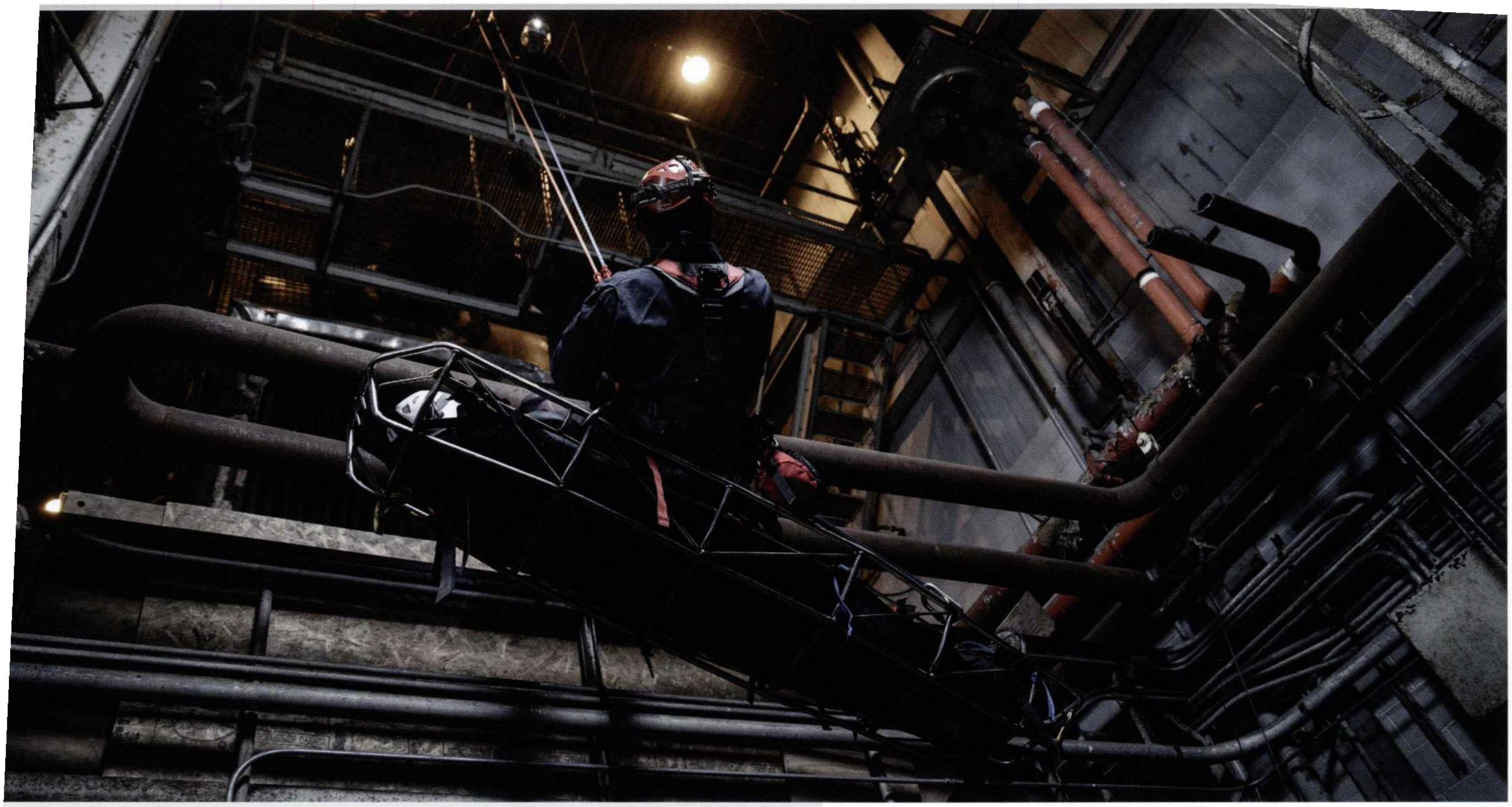
Change Over



Stop

Help

Figure 32-2: Commonly Used Hand Signals



PART 07

Rescues

CHAPTER 33

Putting It All Together

LEGEND: Anchor Grip Load

TERMINAL LEARNING OBJECTIVE

The student will describe the L.A.S.T. concept and how it applies to rope rescue.

ENABLING LEARNING OBJECTIVES

1. Describe hat the four parts of L.A.S.T. mean
2. Describe how to size up an incident
3. Describe how rope rescue skills are used to meet the L.A.S.T. objectives
4. Describe how to recognize incident hazards

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.1.2 | 5.1.3 | 5.2.24

So how does all this fit together when the call comes? Your team has done the preparation: learned the skills, equipped itself fully and developed the command structure. The dispatch system is established and the team's rescue preplan is set up. Hopefully the team's first few rescues will be real-time training, so that responses can be polished and any critical problems that were not apparent during the planning stage are discovered. How the team performs on practice rescues will be very close to how it will perform during the real thing.

One way to organize a rescue response is through the ***L.A.S.T.*** format. L.A.S.T. stands for Locate, Access, Stabilize and Transport. Originally developed for the generic search and rescue response, it also applies to rope rescues.

The discussion below uses the personnel terminology used in the Incident Command System chart in Chapter 32. The medical team will be the first to access the subject. The rigging team is responsible for the initial setting of anchors and systems as required to assist the medical team in its role.

LOCATE

On most rescues, the subject's specific location is known, but often, particularly in wilderness areas, only the general area is known. This may also be true in the urban environment in the case of a collapsed structure or a confined space incident. The first clue will be the dispatcher informing you of the location of the incident. Pretty basic, but that is how it usually starts. Based on the information available, the operations chief develops a checklist of what each team member will do upon arrival.

Once on the scene, the ***size-up*** begins. For a rescue, this is the initial information needed to determine how to access and stabilize the subject. Consider the following:

- Location and number of subjects
- Is voice contact with the subject possible?
- Steepness of the terrain
- Looseness of the soil. How secure is the footing?
- Distance. What lengths of rope will be needed?
- Alternate access routes. Is there a route nearby that can be walked or driven?
- Anchor options
- Edge protection concerns
- Objective hazards. Usually rockfall but do not forget traffic
- Parking space if a truck will be used for the anchor
- Working room for the systems and belays
- Evacuation route. Will it be easier and safer to raise or lower the subject?

Sources for this information include:

- Law enforcement/rangers
- Emergency responders
- Witnesses
- Participants, such as other occupants of a vehicle
- Subject who can tell you how many were involved
- Visual inspection

Sometimes the subject is visible and sometimes not. Visibility may be better when looking at the cliff or the side of the building, but not from the top where the rescuer's descent will begin. Rescue teams in Southern California often deal with a lot of chaparral, a thick brush that can limit visibility to less than 20 feet. In these cases a spotter or a drone in position to see both the subject and the rescuers can guide the rescuers to the point above the subject to set the anchors or during the descent to the subject's location.

Vehicles over an embankment are the most likely situations to have multiple subjects. Occupants might have been ejected and they could be located anywhere from the edge of the road to well below the vehicle and some distance on either side. This type of rescue requires a careful search of the fall line down to and below the vehicle. The sources of information interviewed during the size-up will help determine the number of subjects involved. Check the car for personal belongings or signs of injury that would indicate additional occupants. The best information is from a coherent occupant of the vehicle. If the occupant's information is unreliable, then a search may be required.

Next, determine the subject's condition. To do this the medical team must gain access to the subject.

ACCESS

As the operations chief completes the size-up, they provide information to the rescue supervisor, the medical team and the rigging team leader. With this information, the rigging team leader can anticipate the systems that will be needed and the medical team can anticipate the medical equipment needs. This saves time by preparing equipment prior to the initial briefing. During the briefing, the tactical plan for the rescue is developed and equipment needs and set-up are finalized before the medical team starts over the side.

Remember these basic rules when developing the plan:

- Protect the rescuer
- Protect the subject
- Prepare for the unexpected
- If you go down a rope, be able to come back up

With these in mind, determine the best method to reach the subject. The medical team can:

1. Walk down
2. Walk down with a hand line
3. Walk down using a Prusik hitch self-belay on a fixed line
4. Rappel
5. Be lowered by a lowering system

In some cases the best route to the subject will be from below. Rescuers may still need to set anchors above the subject to provide a safety line while reaching the subject or for setting up the systems for an evacuation. Once the subject is reached, the medical team can determine the actual situation and ***stabilize*** it.

STABILIZE

As the rescue continues, the medical team must make sure that the subject's condition will not deteriorate. In Chapter 24 we discussed the three types of stabilization:

1. Physical: Add a harness and a belay. Move to a safe place
2. Medical: Provide the appropriate treatment and then transport
3. Emotional: Communicate; let the subject know the rescue plan

TRANSPORT

The same rules that apply for access apply when choosing the best way to transport. The training and experience of the team and the subject's condition will help the rescue supervisor and the medical team decide if this is a litter evacuation or not. It will also determine if a low angle or high angle evacuation will be best.

When the transport phase is completed, the rescue is over for the subject, but not for the team. The next step is to gather the team equipment, inspect, complete the documentation and then prepare the team for the next call.

Most important, review what was done, discuss what went well and what did not because the real rescue is the best learning experience.

Notes

PART 08

Special Applications

CHAPTER 34

Rope Access

LEGEND: Anchor Grip Load

TERMINAL LEARNING OBJECTIVE

The student will describe the differences between rope access and rope rescue and how rope access techniques and equipment are used.

ENABLING LEARNING OBJECTIVES

1. Describe the significant differences between rope access and rope rescue methods
2. Ascend a fixed rope, pass an obstruction, continue the ascent, convert to descent, pass the obstruction and descend to the starting point
3. Perform a rope to rope transfer
4. Demonstrate a partner rescue
5. Demonstrate horizontal movement by using line transfer techniques

NFPA® JOB PERFORMANCE REQUIREMENTS

This chapter provides information that addresses the following job performance requirements of NFPA® 1006 Standard for Technical Rescue Personnel Professional Qualifications (2021).

5.2.12 | 5.3.3 | 5.3.7 | 5.3.9 | 5.3.11

ROPE ACCESS

Rope Access, as the name implies, refers to using rope skills to get to vertical locations to perform work. An early example was cavers in Georgia using their vertical gear to wash windows on Atlanta high-rises. Because of their need to access gates, spillways and other parts of dams the Bureau of Reclamation was an early adopter of rope access techniques and developed one of the first manuals to train their crews.

In the mid-1990s, safety inspectors were beginning to question the safety of workers on rope, particularly since there appeared to be a lack of safe work standards. Loui McCurley and Steve Hudson (PMI), Mike Roop (ROCO) and Jim Frank (CMC) got together to draft a Safe Practices Standard for rope access workers.

That led to the formation of the Society of Rope Access Technicians or SPRAT. Leading practitioners such as Jan Holan (Ropeworks) and Steve Beason (Bureau of Reclamation) soon joined the project and assisted with the drafting of the Certification Requirements. Once the requirements were finalized the testing of SPRAT technicians began. SPRAT provides certification that allows a Rope Access Technician to document that they have the training and experience to work safely on line.

Rope access work and rope rescue differ in several aspects:

Rope Access

- Rope access technicians are certified workers that perform a planned work task.
- The rope system is designed to support one technician.
- The work location is ALWAYS inspected prior to commencing work.
- A work plan including safety is written and approved before work starts.
- There is little or no interaction with the public.
- The work needed is rarely time critical.

Rope Rescue

- Rescue locations are not planned ahead of time and are often difficult to access.
- Rescues usually involve several people and often more than one agency.
- Rope rescue personnel are trained first responders that interact with the public.
- Rescues involve patient treatment, patient packaging and patient transport.
- A rescue is time critical based on the medical condition of the patient.

Another significant difference is government oversite. OSHA and the states that have their own occupational safety programs focus on safe work practices. While Federal OSHA does not have any specific standards relating to rope access, the State of California, City of New York, Province of Alberta and some others do. This is different than the standards that apply to rope rescue operations.

Chapter 34 introduces some of the rope access techniques that might be useful in certain rescue situations. They should be practiced ahead of time with a knowledgeable instructor. If you are interested in rope access work, contact SPRAT at sprat.org for the training program closest to you.

ANCHORS

Anchorage systems used as the primary support within a main or back-up system shall have a minimum strength of either 12 kN (2700 lbf), or two times the maximum arrest force of the back-up system when used in accordance with manufacturer specifications, whichever is greater.

A re-anchor is a fixed anchor established below the main anchor and is usually used to direct the working line away from a hazard or to a better location. A loop of the working rope is left below the re-anchor before it is connected to the re-anchor.

A deviation is also used to change the direction of the rope system, but the rope is not attached to the anchor. Instead, the rope just runs through a carabiner or other connector. This keeps the primary load on the main anchor and a much lower side load on the deviation. In practice, a deviation must be rigged so that the technician can reach the rope below the carabiner during the transition.

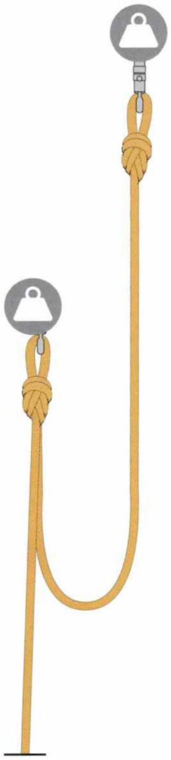


Figure 34-1: Re-Anchor

DESCENDING

This is just rappelling and any descent control device should enable the user to stop and work hands-free. Brake Bar Racks were the common tool for window washers working on tall buildings and are still a good choice for work that only requires a descent, particularly for very long descents that may overheat an auto-stop descender. A tie-off bar makes tying off for frequent stops much more convenient.

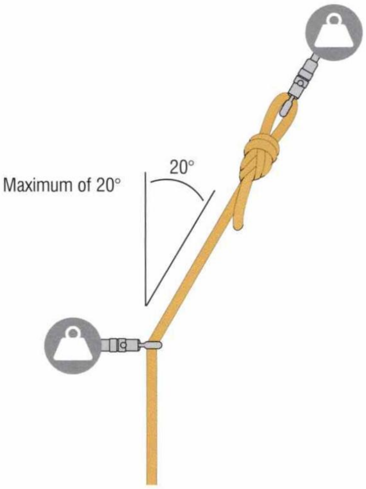


Figure 34-2: Deviation

Auto-stop descenders are used for most rope access work and are required by some of the rope access standards. Examples include the CLUTCH, Petzl I'D, and the Climbing Technology Sparrow. A lever that controls the descent is operated by one hand with the other hand holding the rope as a back-up. If the lever is released, the descent stops. Some models now have a double-stop feature, which stops the descent if the rappeller panics and over pulls the handle.

USING THE CLUTCH

Due to its multi-function design, the CLUTCH is a great device both for use in systems and for individual rope work. The CLUTCH will provide a safe and stable work position when the Control Handle is in less than a vertical orientation on the Stop/Stand By side of the device. This is a useful feature for technicians who need to frequently go hands free.

See Chapter 22 for more on ascending and Chapter 21 for more on descending with the CLUTCH

ASCENDING

The most common ascending system used by Rope Access Technicians is the Frog System covered in Chapter 22. On a harness designed for rope access work, a chest ascender may be built into a full-body harness or may be connected to the front of the harness using a triangular screw link and a short length of web to hold the ascender against the chest for best efficiency. A handled ascender with an attached foot loop is positioned above the chest

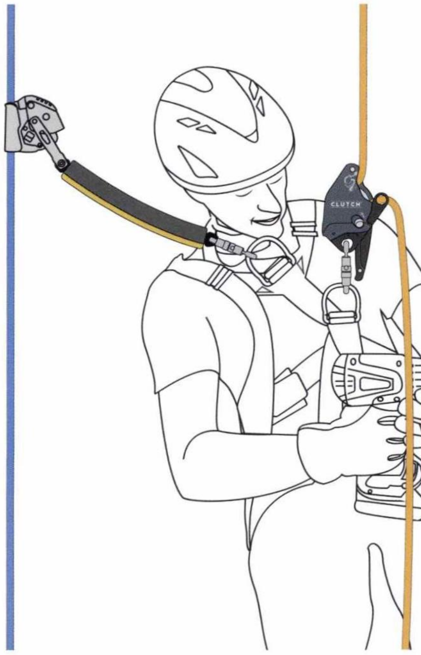


Figure 34-3: Work Positioning with the CLUTCH

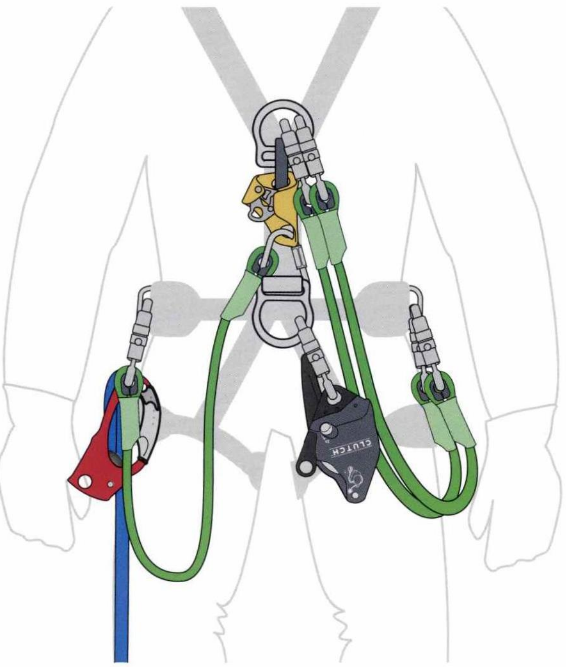


Figure 34-4: Rope Access Technician Harness Set Up

ascender, allowing the hands to be used to assist in the ascent. A length of web or lanyard connects the handled ascender to the front waist D-ring on the harness for the second point of connection to the rope.

For a shorter ascent, where an immediate rappel is expected, an auto-stop descender can be used instead of the chest ascender. The descender connects to the waist of the harness. After stepping up in the foot loop, the rope must be pulled through the descender to take out the slack. This is much less efficient than the rope being pulled through the chest ascender by the standing movement, but the conversion to a rappel is simply a matter of disconnecting the handled ascender from the rope. The rope can be redirected up through a small pulley attached to the handled ascender, allowing an easier downward pull to lift the descender.

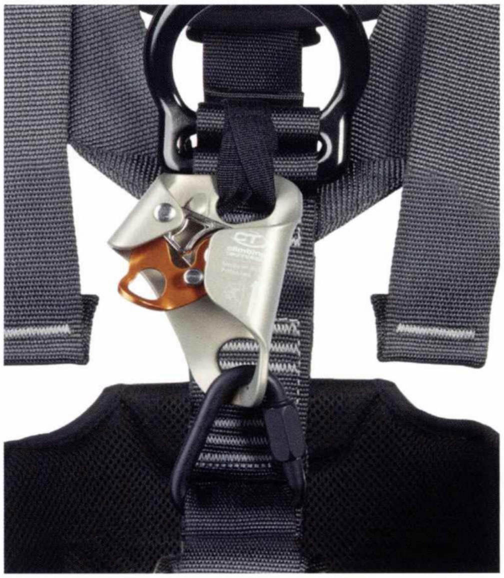


Figure 34-5: Chest Ascender

BACK-UP SYSTEM

Since rope access is work at height, fall protection is an essential part of the system. Safe practices for rope access work require that a back-up system shall be used with any main system, with the exception of dual main systems. The attachment to the back-up system, or using a dual main, provides the second point of connection discussed in Chapter 02. If required by the manufacturer of the back-up device, use the appropriate shock absorber.

Because of the possibility that an ascender could come off of the rope under certain conditions, some rope access schools consider an ascender to be only a half point of connection. When ascending, the two ascenders on the working line count as one point and the back-up device on the safety line becomes the second point. Descent is simpler as the descent control device on the working line is obviously one point of connection, so only a second is required. For rope access work, putting the second point of connection on the safety line also achieves the requirements of an industrial fall protection system.

The sternal attachment point may be used as an alternative fall arrest attachment in applications where the dorsal attachment is determined to be inappropriate by a competent person and there is no chance the direction of fall will be other than feet first.

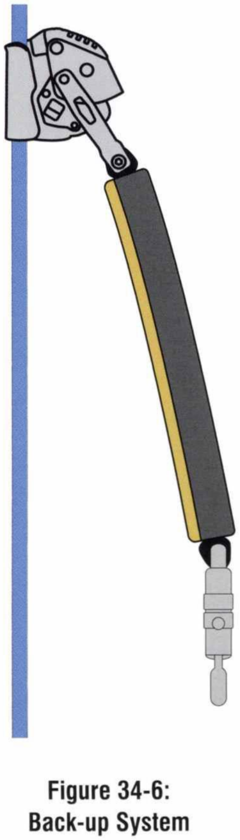
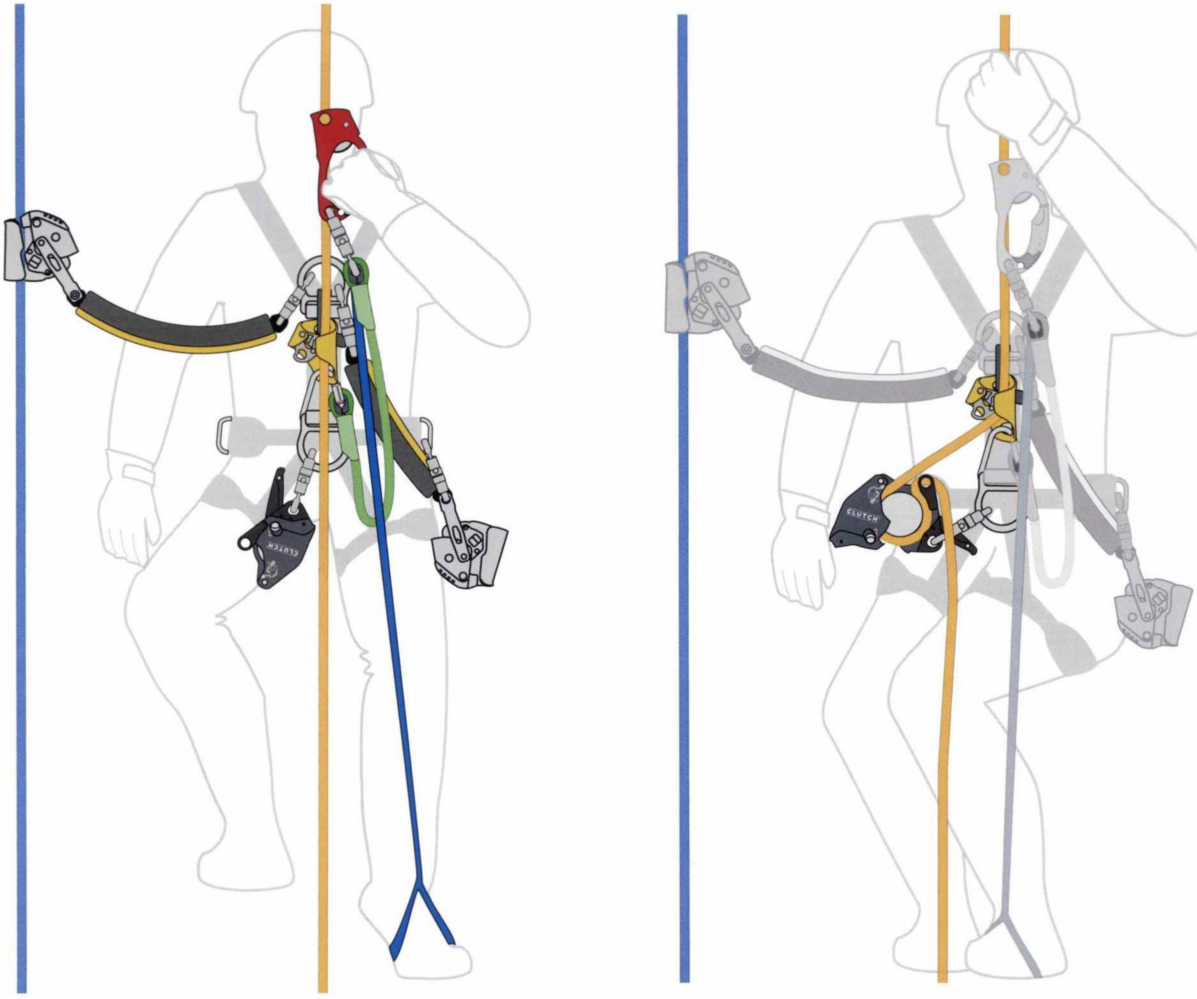


Figure 34-6: Back-up System

CONVERTING FROM ASCENT TO DESCENT

Where access to the top is available, descending is easier than climbing. The technician rigs the descending device, the back-up system and then descends. When this is not possible, the Rope Access Technician will often ascend up from the bottom and then convert to a descent.

If it is a short climb, the ascending system can be rigged using a descender rather than the chest ascender. This is not as efficient since the climber must pull the rope through the descender for each step up. The conversion to a rappel is then just a matter of removing the handled ascender with the foot loop.



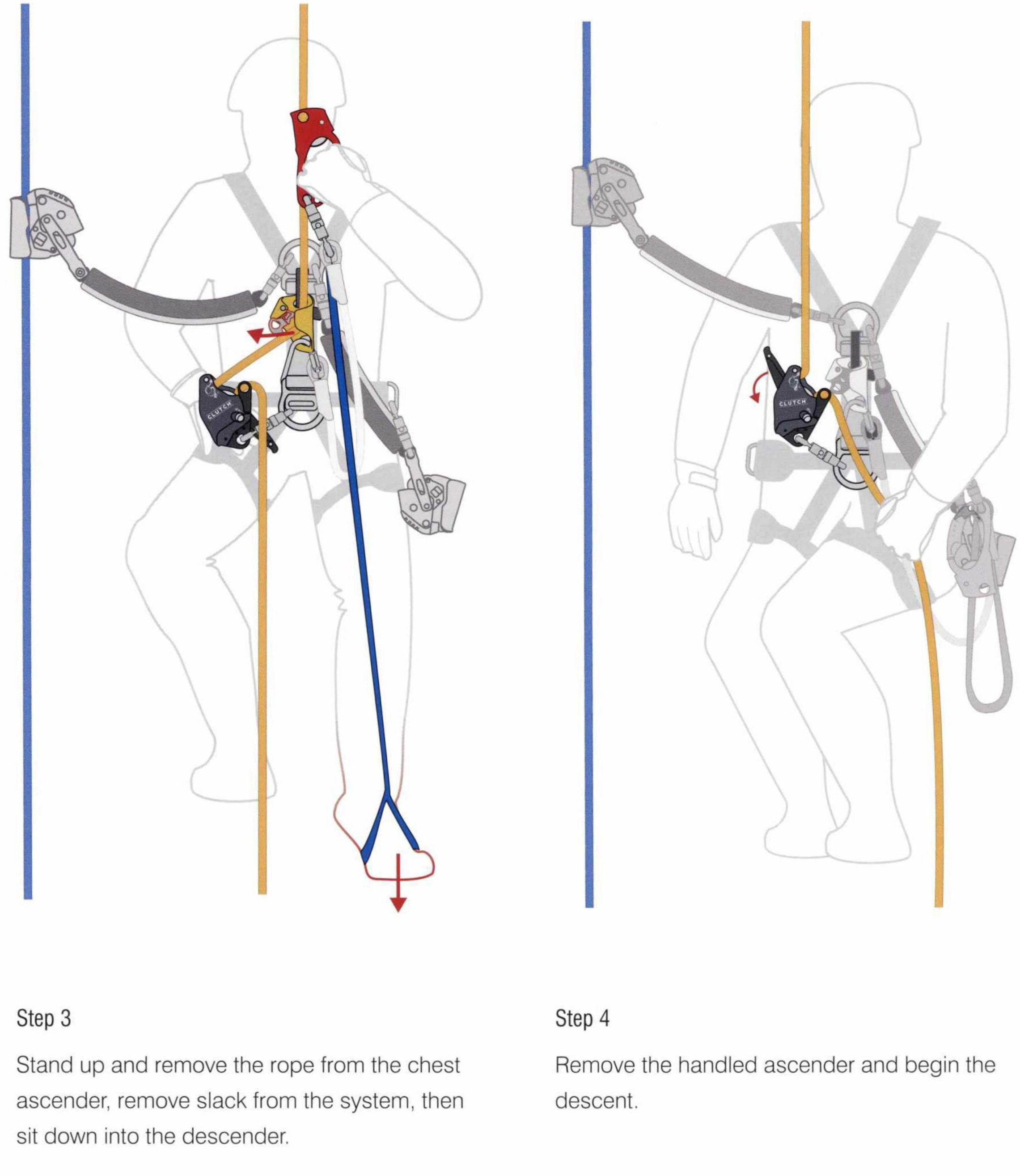
Step 1

For a longer ascent, using the chest ascender is much more efficient. To change to a descent, sit down on the chest ascender.

Step 2

Add your descender below your chest ascender. Remove slack from the system.

Figure 34-7: Converting from Ascent to Descent



Step 3

Stand up and remove the rope from the chest ascender, remove slack from the system, then sit down into the descender.

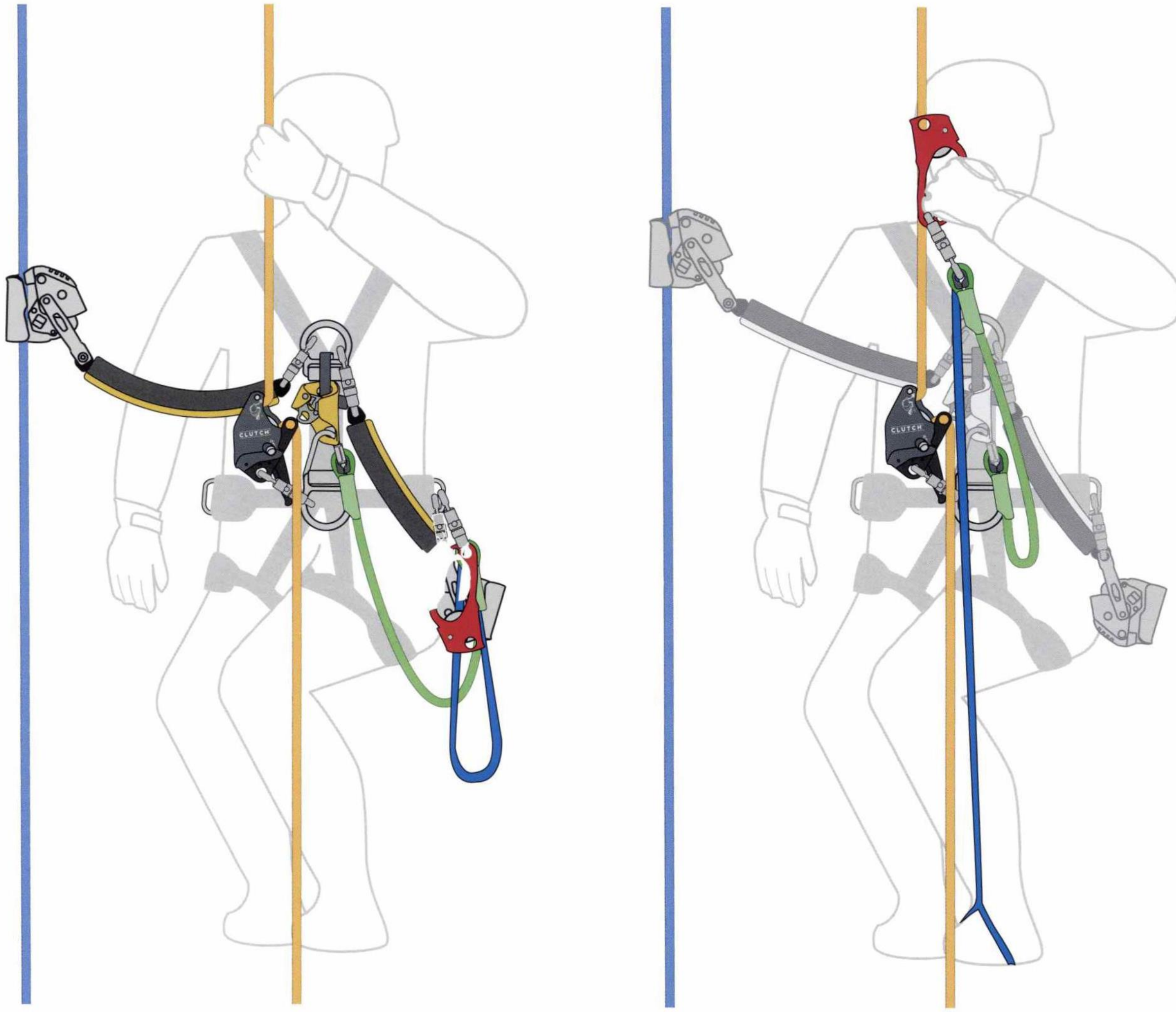
Step 4

Remove the handled ascender and begin the descent.

Figure 34-7: Converting from Ascent to Descent

CONVERTING FROM DESCENT TO ASCENT

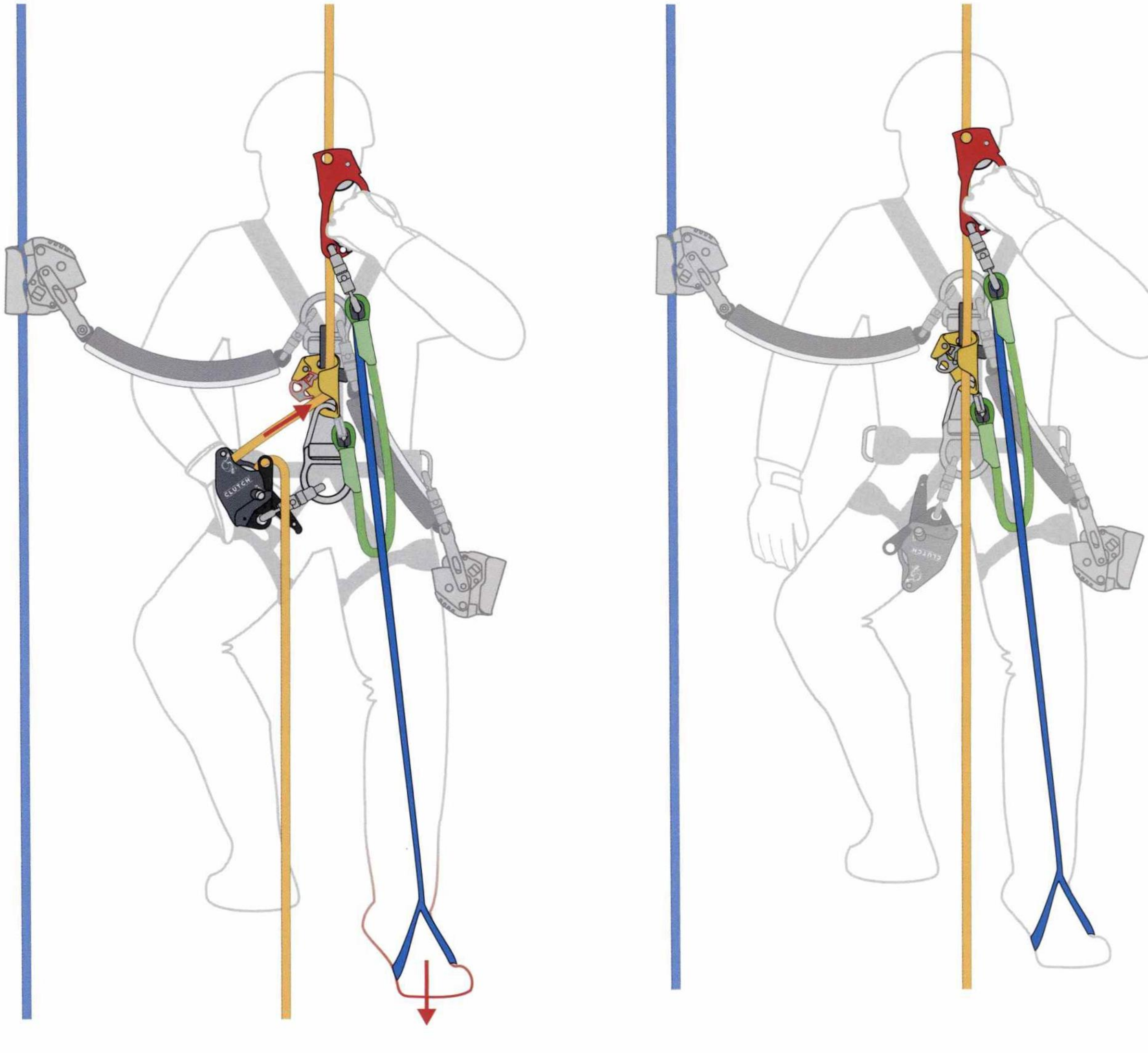
When the rope does not reach all the way to the bottom or the egress is at the top, then a climb back up may be the best way out. If the climb is just a short distance, the descender can be used instead of the chest ascender (see Chapter 22).



Step 1
Lock off the descender.

Step 2
Add a handled ascender with foot loop above the descender.

Figure 34-8: Converting from Descent to Ascent



Step 3

Stand up to create slack between the handled ascender and the descender, which will allow you to connect the rope to your chest ascender.

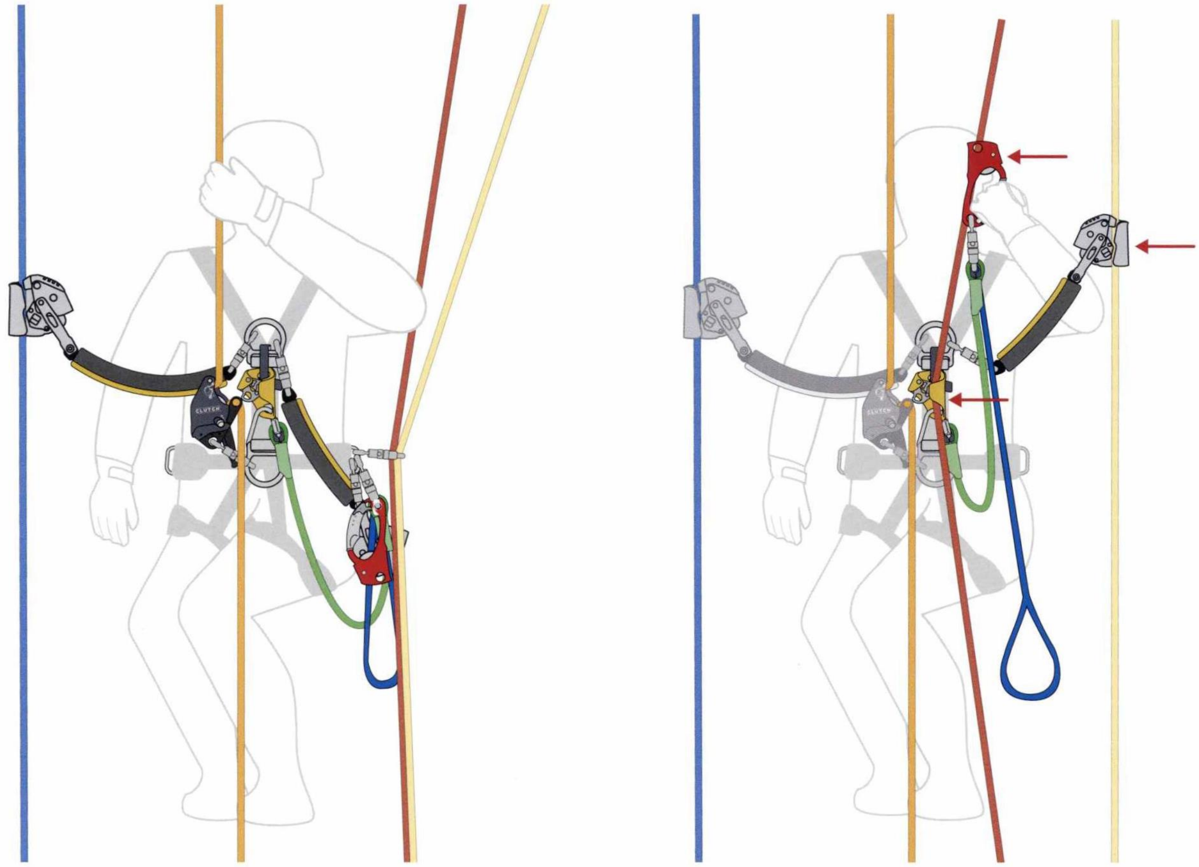
Step 4

Sit down on the chest ascender and remove the descender.

Figure 34-8: Converting from Descent to Ascent

ROPE TO ROPE TRANSFER

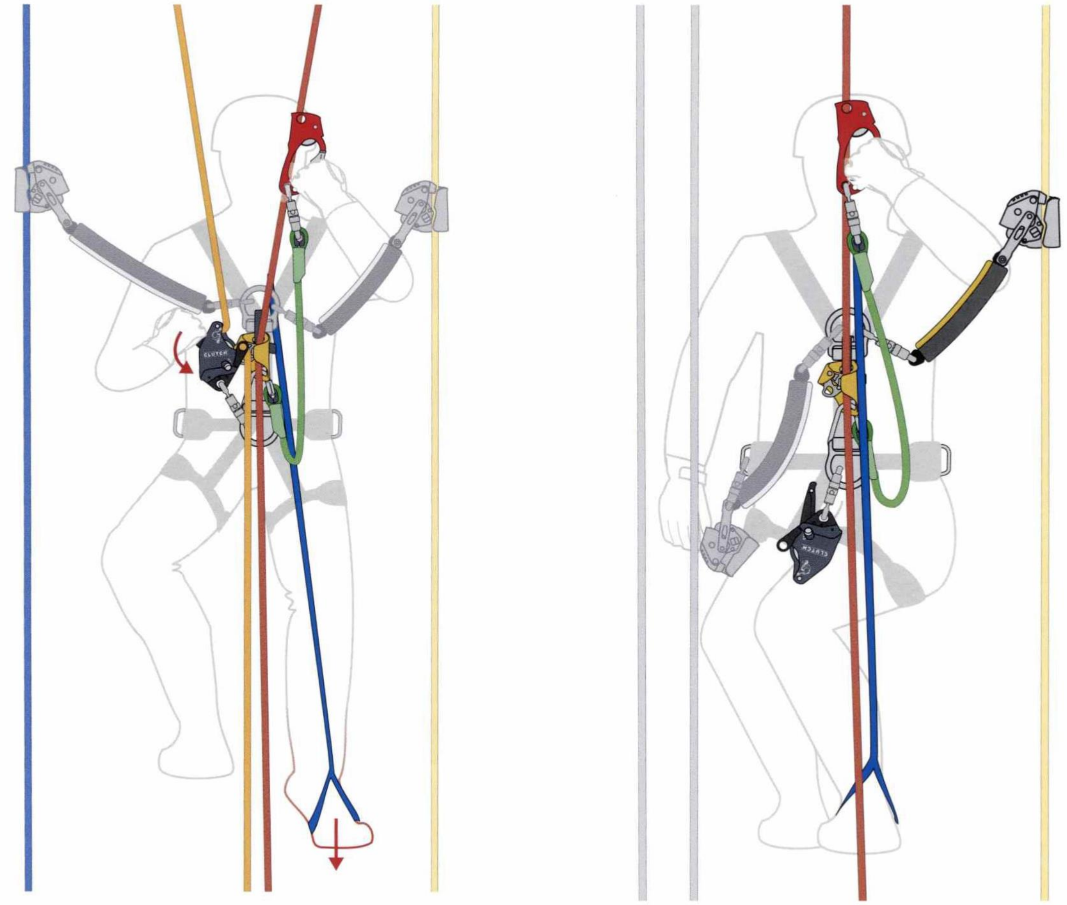
If two or more rope systems are rigged and the technician is required to move between them, then clip the second set of ropes through a carabiner to your harness before ascending so that you may reach the second set once in position. Start by changing to a descending system. A second back-up device will be needed. The essential element of the procedure is to always maintain a full point of attachment on the working rope and both safety ropes.



Step 1
Stop and lock off your descender.

Step 2
Add a back-up device to the new safety line. This provides three points of attachment. Attach your chest ascender and handled ascender to the new working line.

Figure 34-9: Rope to Rope Transfer



Step 3

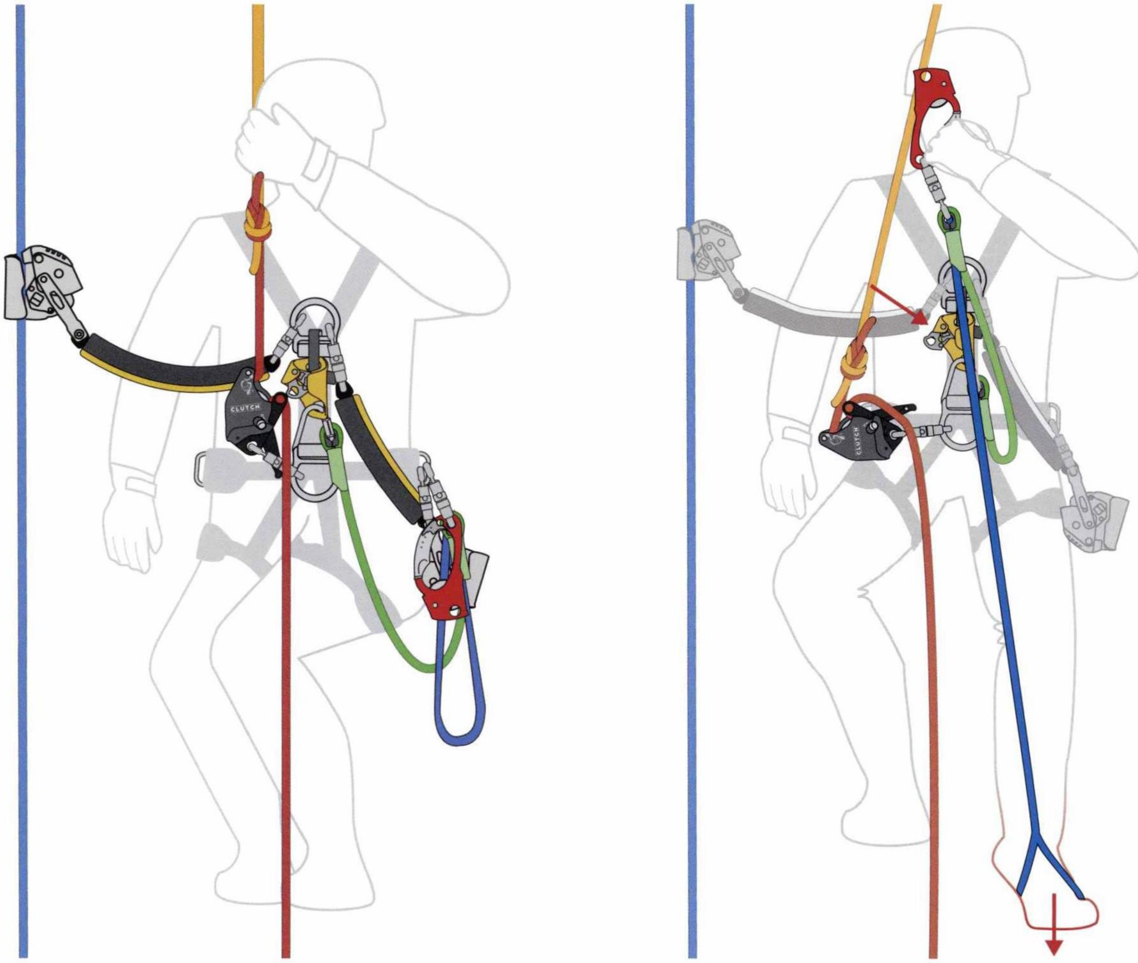
At this point you are in the V between the two rope systems. You can control your horizontal movement by descending on one rope system while ascending on the other rope system. As you continue to move horizontally you become supported by only the new working line.

Step 4

Disconnect from the first rope system. If ascending, continue the ascent. If descending, first convert back to a descending system.

Figure 34-9: Rope to Rope Transfer

PASSING A KNOT - ASCENT



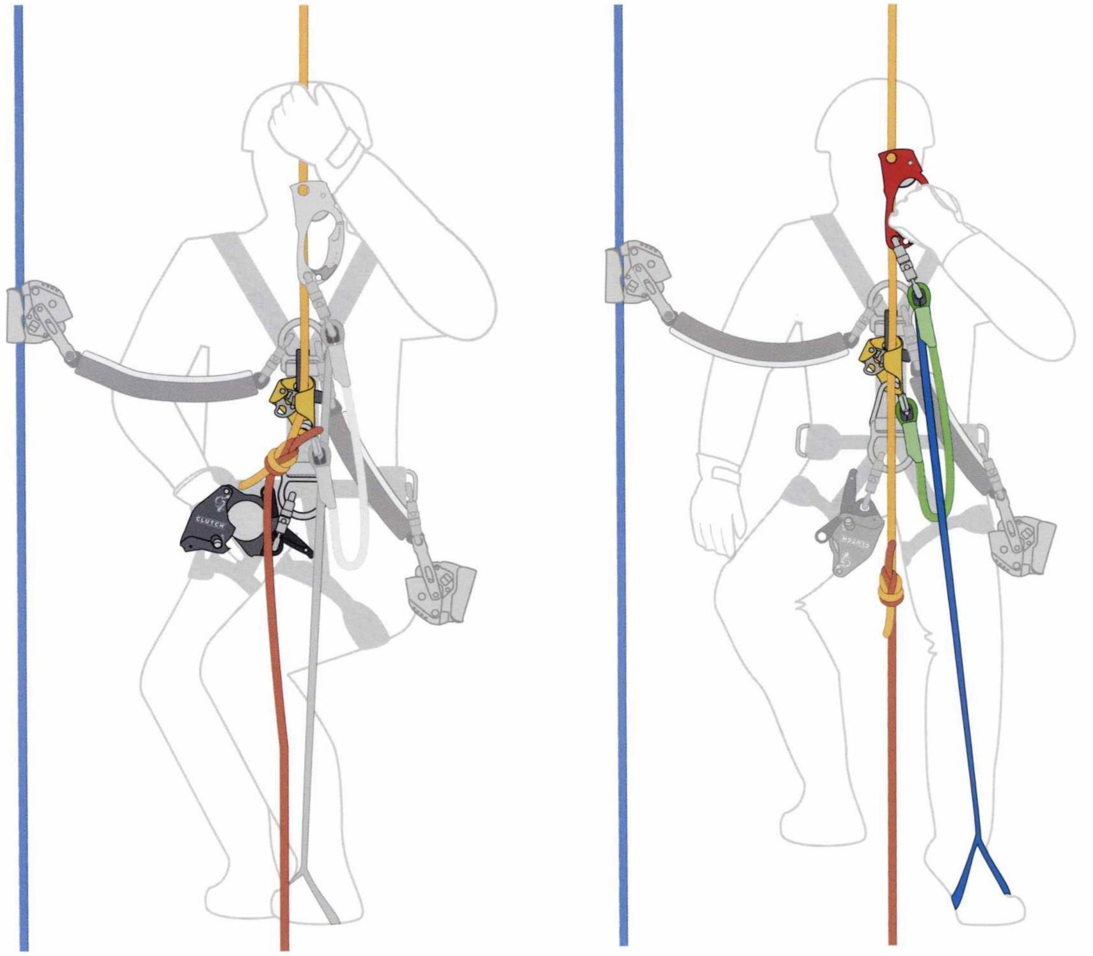
Step 1

When you get close to the knot, convert to a descent system.

Step 2

Stand up in the foot loop connected to the handled ascender. Then insert the rope into the chest ascender above the knot. As you step down, transfer your weight to the chest ascender.

Figure 34-10: Passing a Knot – Ascent



Step 3

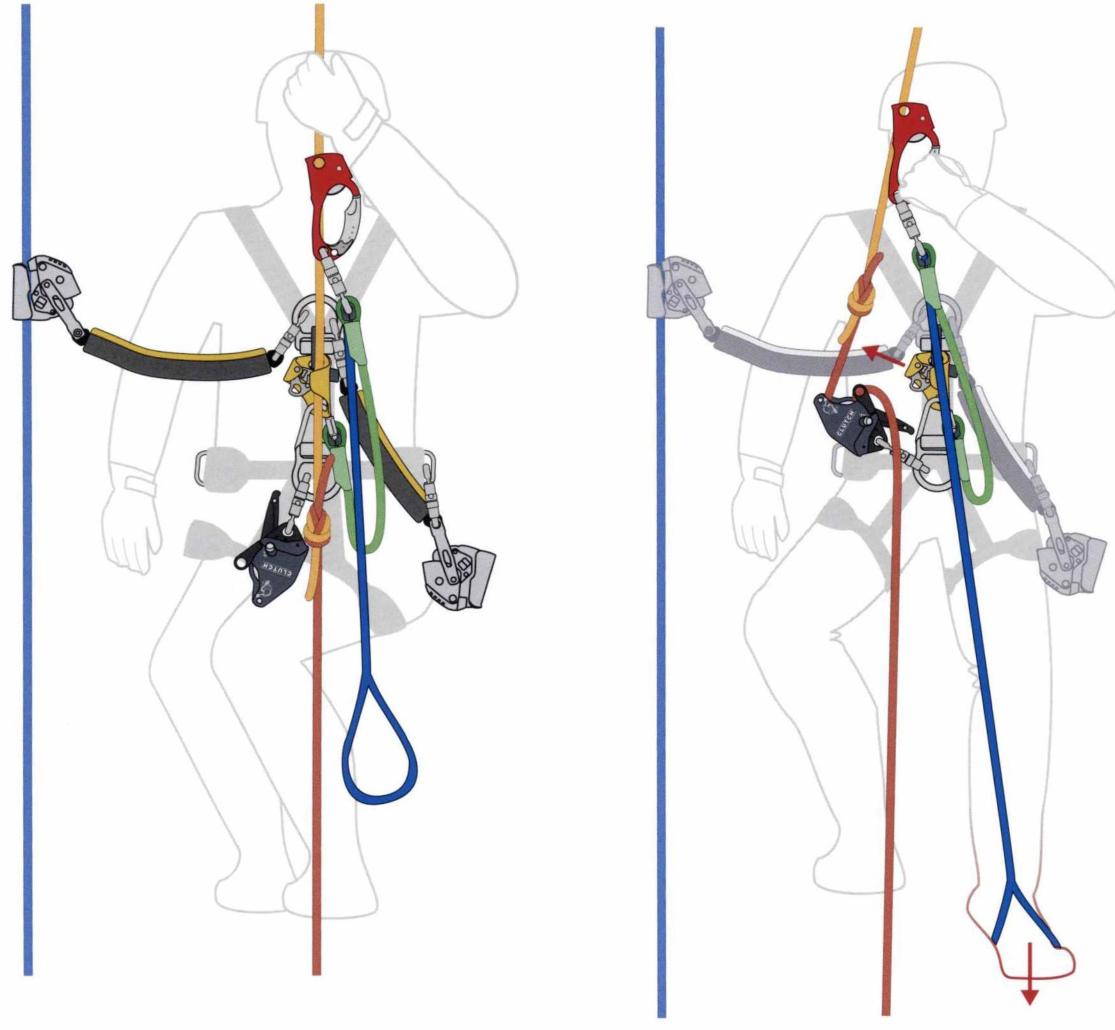
Disconnect your descender from below the knot.

Step 4

Continue your ascent

Figure 34-10: Passing a Knot – Ascent

PASSING A KNOT - DESCENT



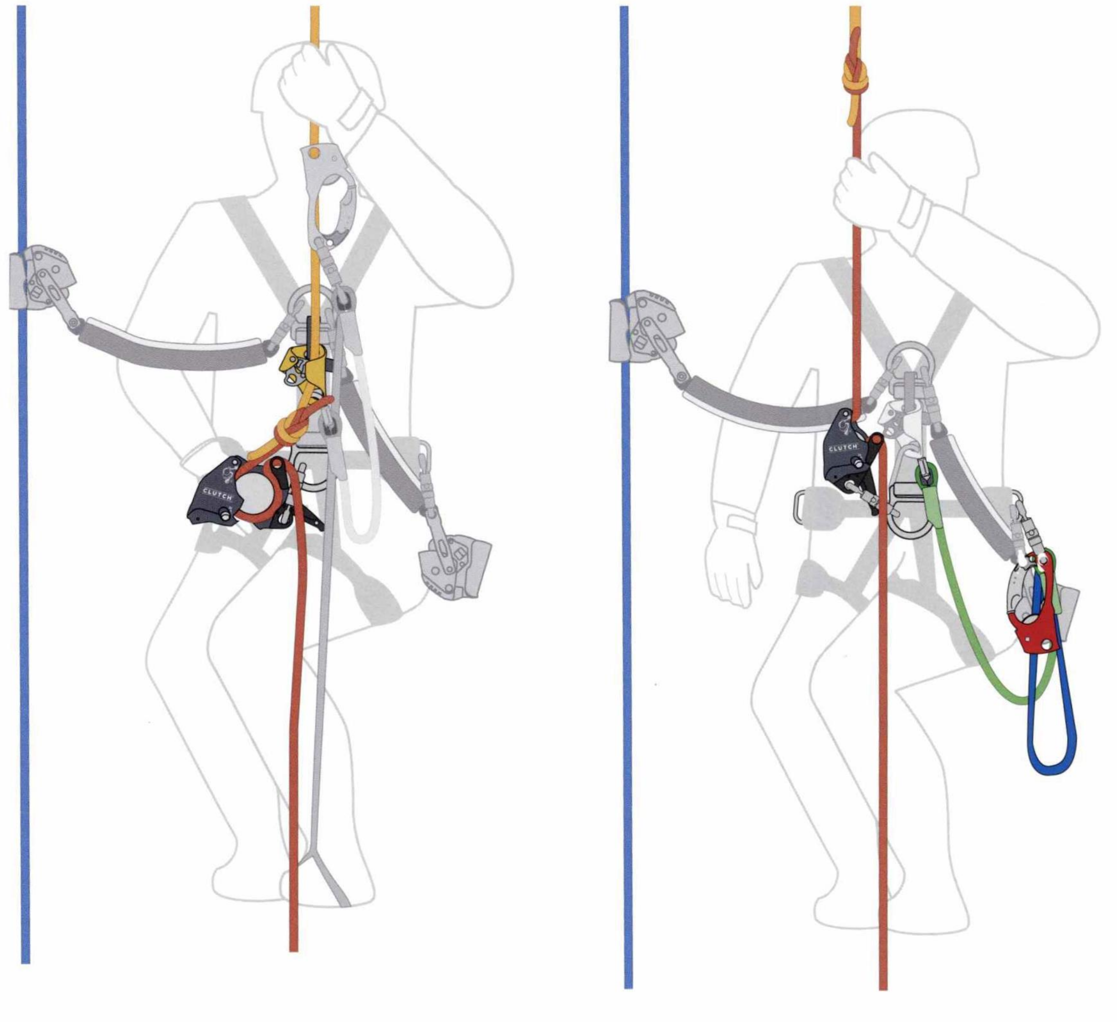
Step 1

When you get close just above the knot, convert to an ascending system. Down climb with your chest ascender until your close to the knot.

Step 2

Rig your descender just below the knot, remove as much slack as possible, and lock off the descender.

Figure 34-11: Passing a Knot – Descent



Step 3

Stand up in the foot loop and remove the rope from the chest ascender. As you step down, transfer your weight to the descender while making sure that the carabiner is not cross loaded.

Step 4

Disconnect the handled ascender and continue your descent.

Figure 34-11: Passing a Knot – Descent

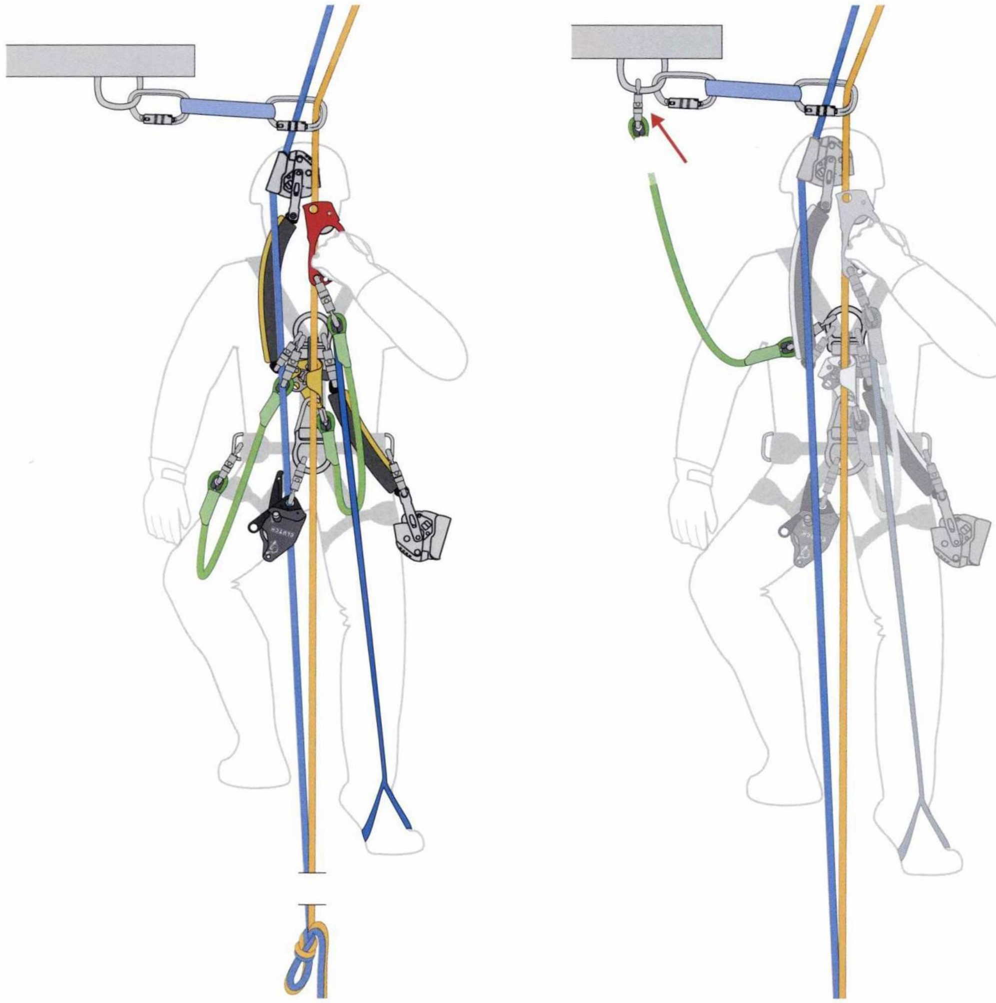
PASSING A KNOT – BACK-UP

Step 1: When the back-up device is close to the knot, add a second back-up device on the other side of the knot: above when ascending, below when descending.

Step 2: Remove the first backup device and continue.

PASSING A DEVIATION - ASCENT

A second back-up is not needed unless rescuing another technician through a deviation. The essential priority in this maneuver is to avoid uncontrolled swings.



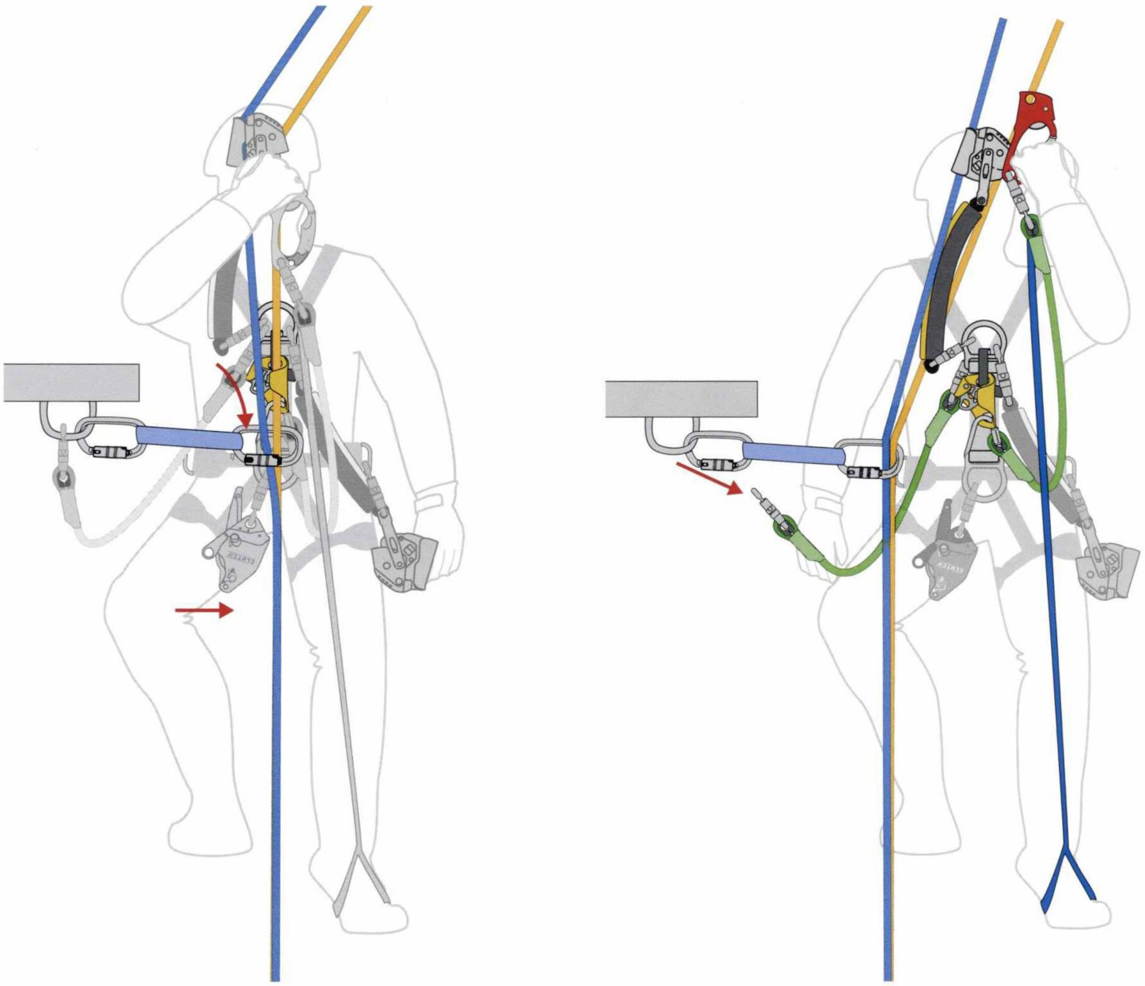
Step 1

Tie a knot 6 to 8 feet below the carabiner so you can pull yourself back to it. Leave enough slack to lower out until you are plumb with the anchor. Stop at a position just below the deviation's anchor point.

Step 2

Connect a lanyard to the deviation's anchor.

Figure 34-12: Passing a Deviation – Ascent



Step 3

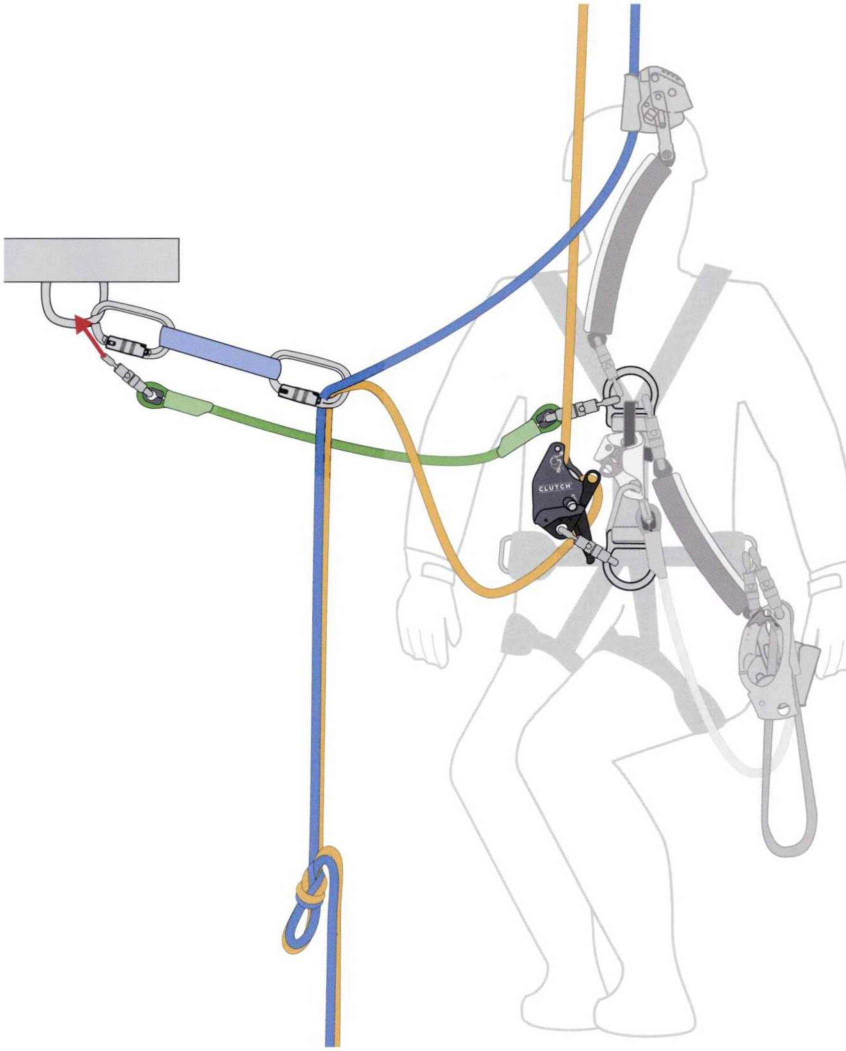
Grab the deviation close to the anchor, pull yourself in to create slack in the system. Disconnect the deviation anchor carabiner then reconnect it below your chest ascender and the back-up device.

Step 4

While holding the main and back-up ropes below the knot, disconnect the lanyard and use the ropes to control sideways movement until directly below the main anchor points. Continue the ascent.

Figure 34-12: Passing a Deviation – Ascent

PASSING A DEVIATION – DESCENT

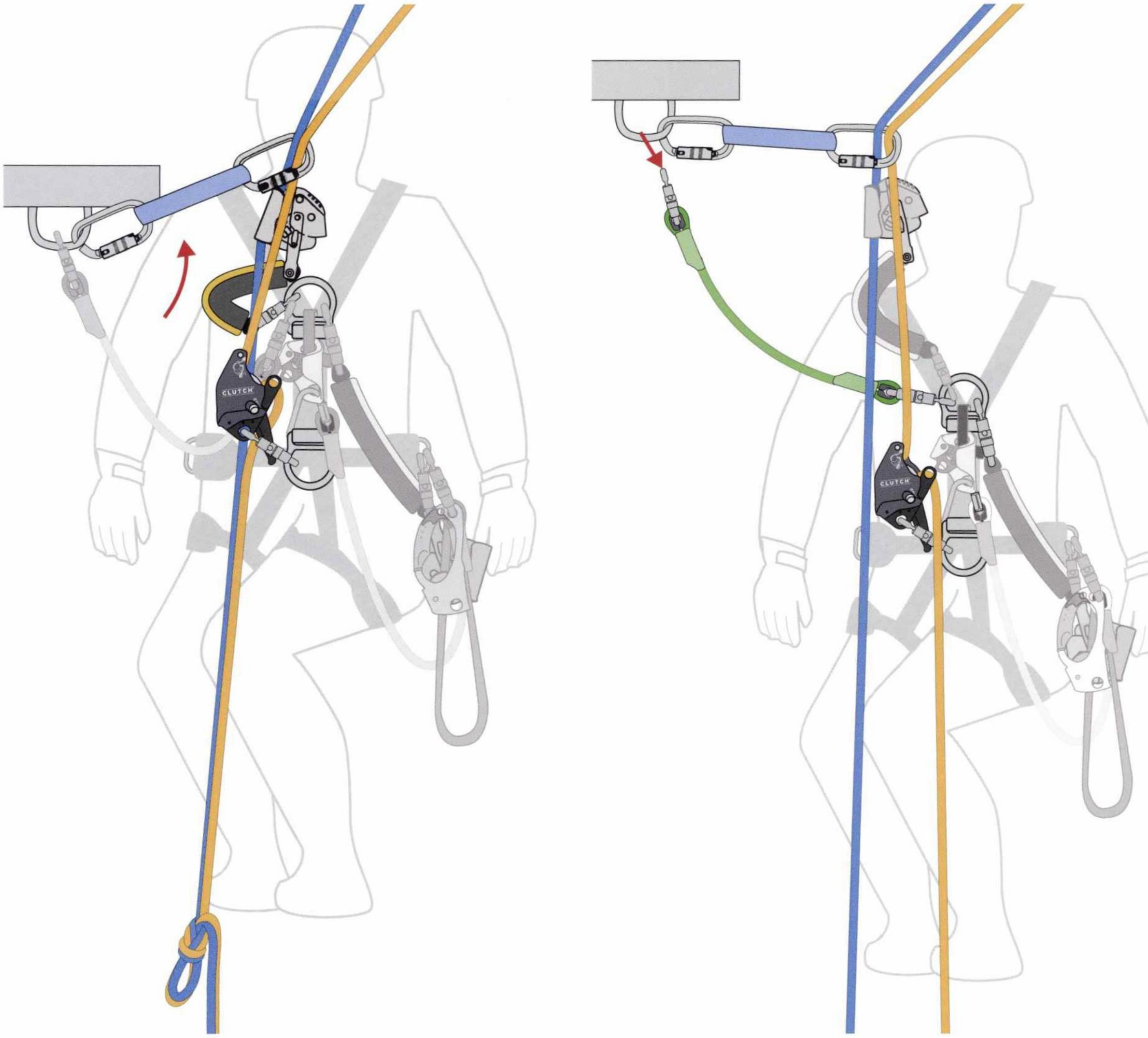


Step 1

In order to pass the deviation, a knot will need to be located 6 to 8 feet below the carabiner as shown in the step one of the previous section, Passing a Deviation - Ascent. When you are at eye level of the deviation, pull the main and back-up ropes until the knot stops at the deviation anchor. Then pull yourself over and connect to the anchor.

Figure 34-13: Passing a Deviation Anchor – Descent

Note: Performing a pick-off rescue past a deviation is an advanced skill. It is not just a matter of combining the pick-off rescue and passing a deviation techniques shown in this chapter.



Step 2

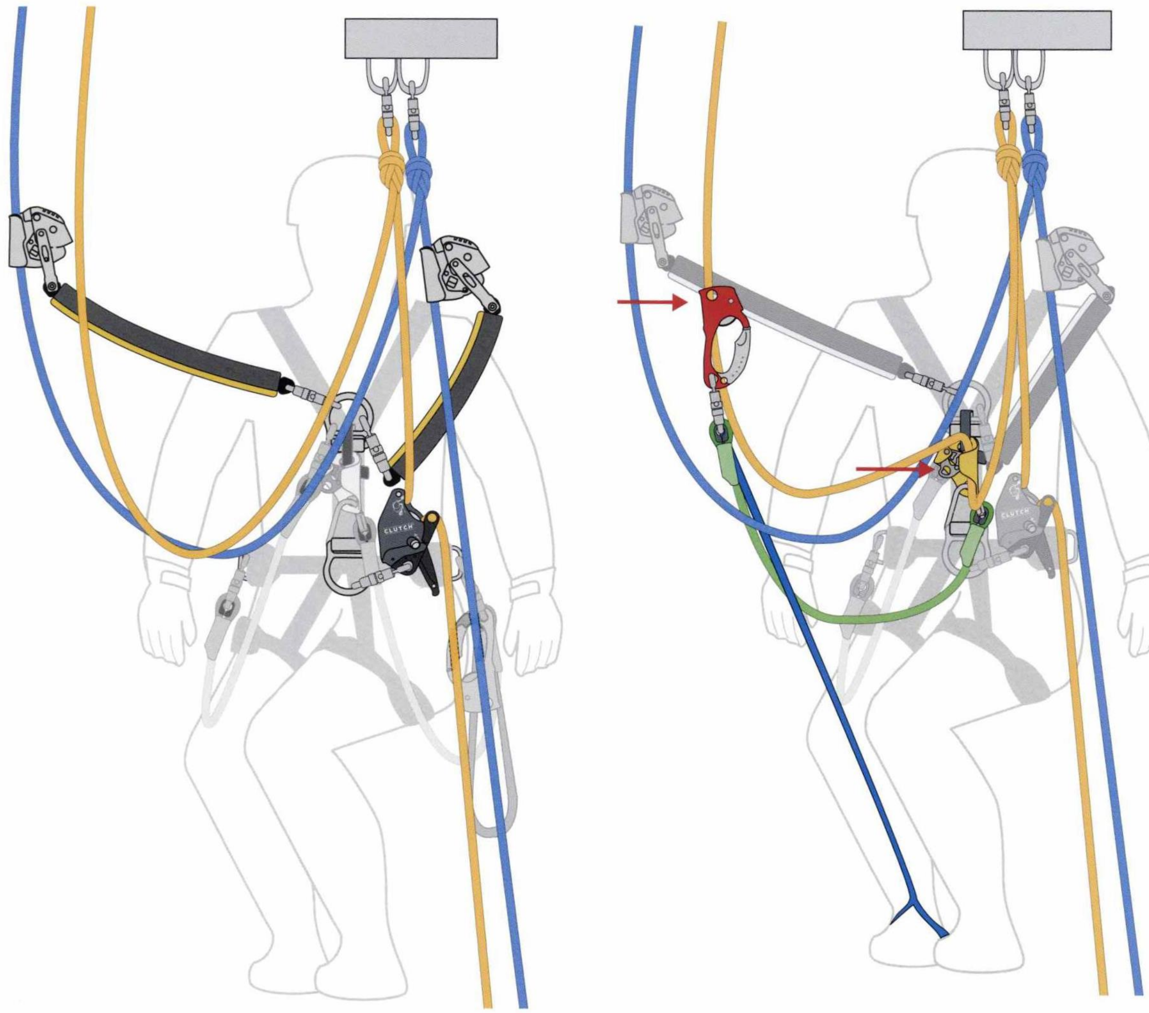
While held close to the deviation anchor by the lanyard, disconnect the deviation anchor carabiner and re-connect it above your descender and back-up device.

Step 3

Disconnect the lanyard and continue your descent. If needed, untie the knot below the deviation.

Figure 34-13: Passing a Deviation – Descent

PASSING A RE-ANCHOR – ASCENT



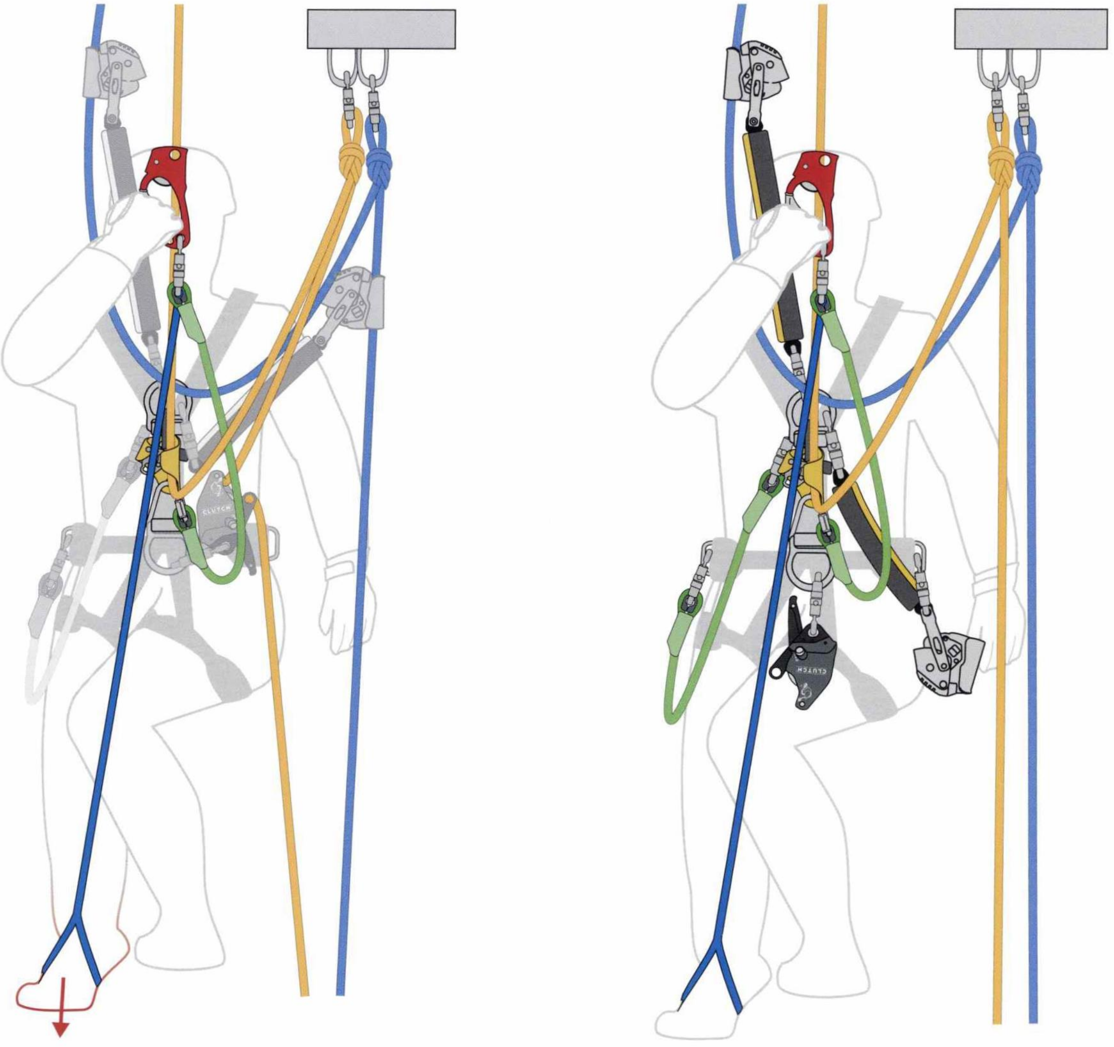
Step 1

Ascend to just below the anchor, stop and convert to a descending system. Place a second back-up device onto the new safety line on the far set of ropes.

Step 2

Attach your handled ascender and chest ascender to the new working line on the far set of ropes. Pull the rope through the chest ascender until there is no slack. Use the descender to lower yourself until you are directly below the new anchor.

Figure 34-14: Passing a Re-Anchor – Ascent



Step 3

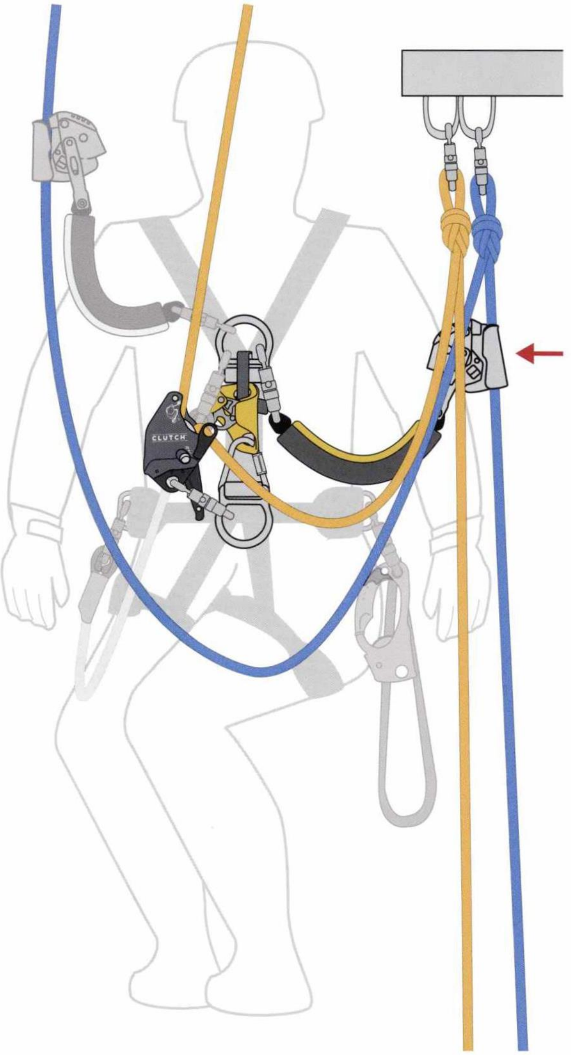
Ascend as necessary to prevent the working line below the chest ascender from becoming loaded.

Step 4

Stop and remove the first back-up device and the descender. Continue the ascent.

Figure 34-14: Passing a Re-Anchor – Ascent

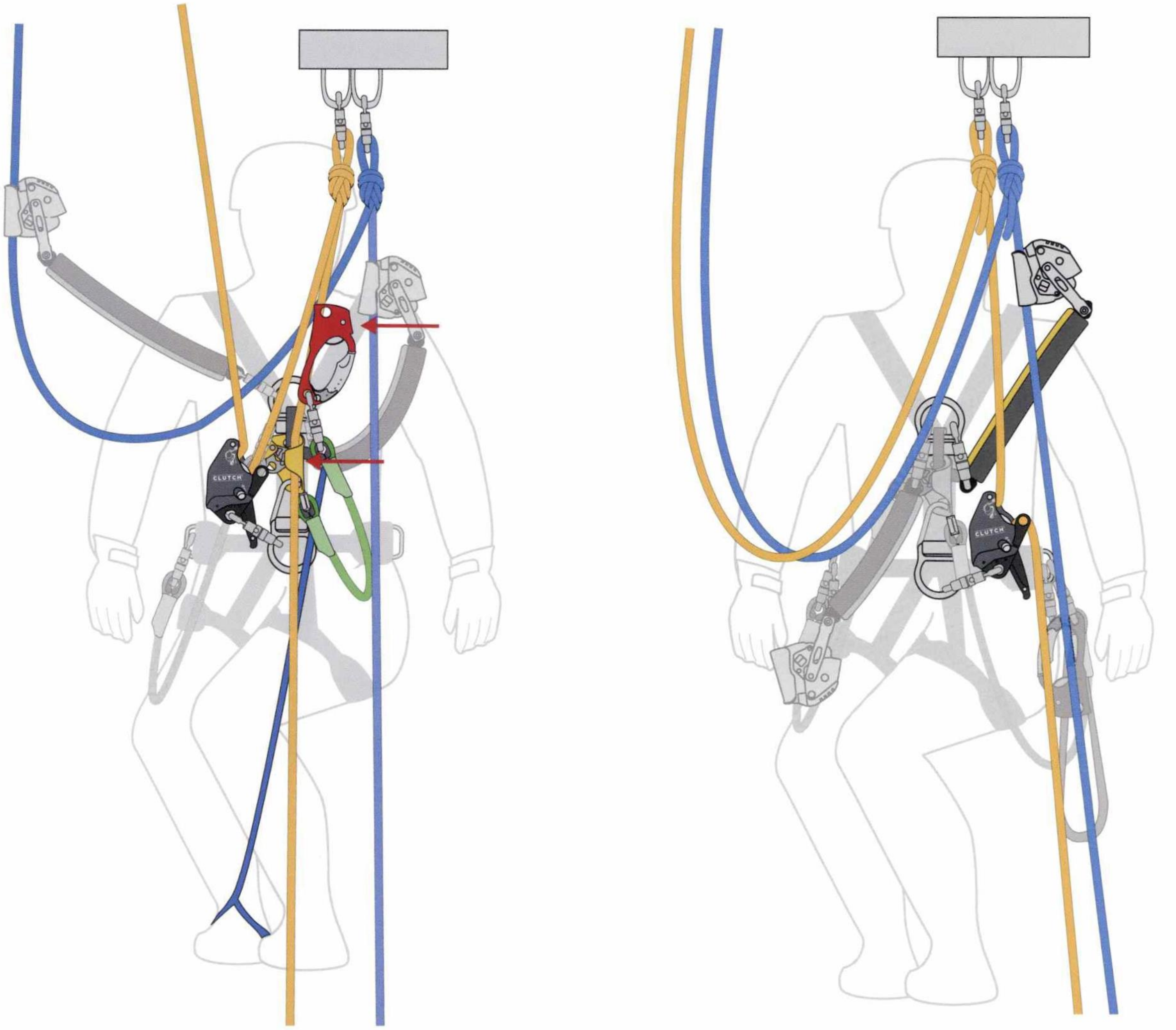
PASSING A RE-ANCHOR - DESCENT



Step 1

Use your descending gear on the ropes you are transferring from and your ascending gear on the ropes you are transferring to. Descend down until you are level with the re-anchors. Place a second back-up device on the back-up rope below the re-anchor.

Figure 34-15: Passing a Re-Anchor – Descent



Step 2

Connect ascending gear on the far set of ropes. Descend down and climb up as necessary until only suspended by the last set of ropes.

Step 3

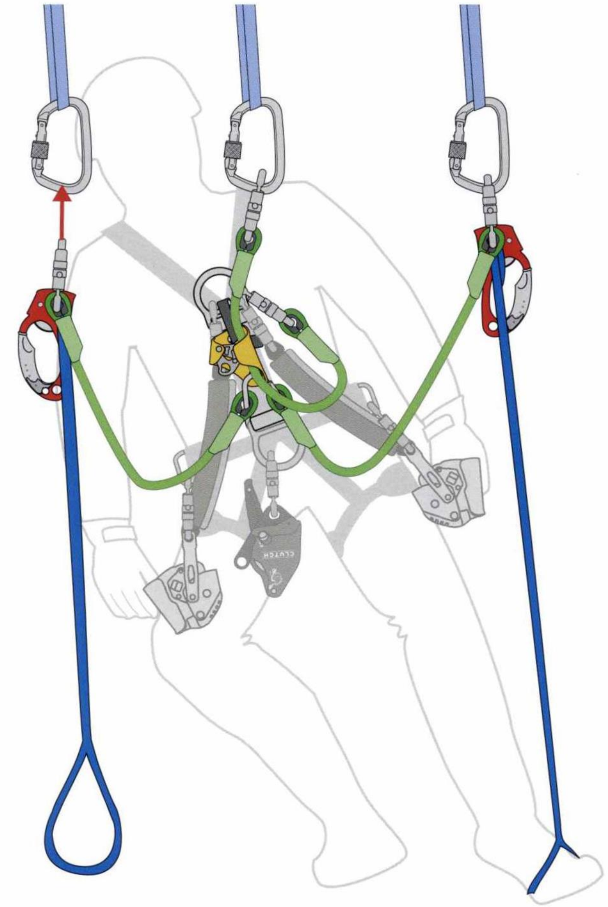
Remove descending gear from the original set and re-install it below chest ascender Switch to descent and continue descending.

Figure 34-15: Passing a Re-Anchor – Descent

HORIZONTAL AID CLIMBING

A Rope Access Technician can also move horizontally below a structure. This usually requires the installation of anchor points as the technician traverses but sometimes the structure may have pre-existing anchor points. Web slings with edge protection wrapped around a beam or beam clamps are the most common types of temporary anchor.

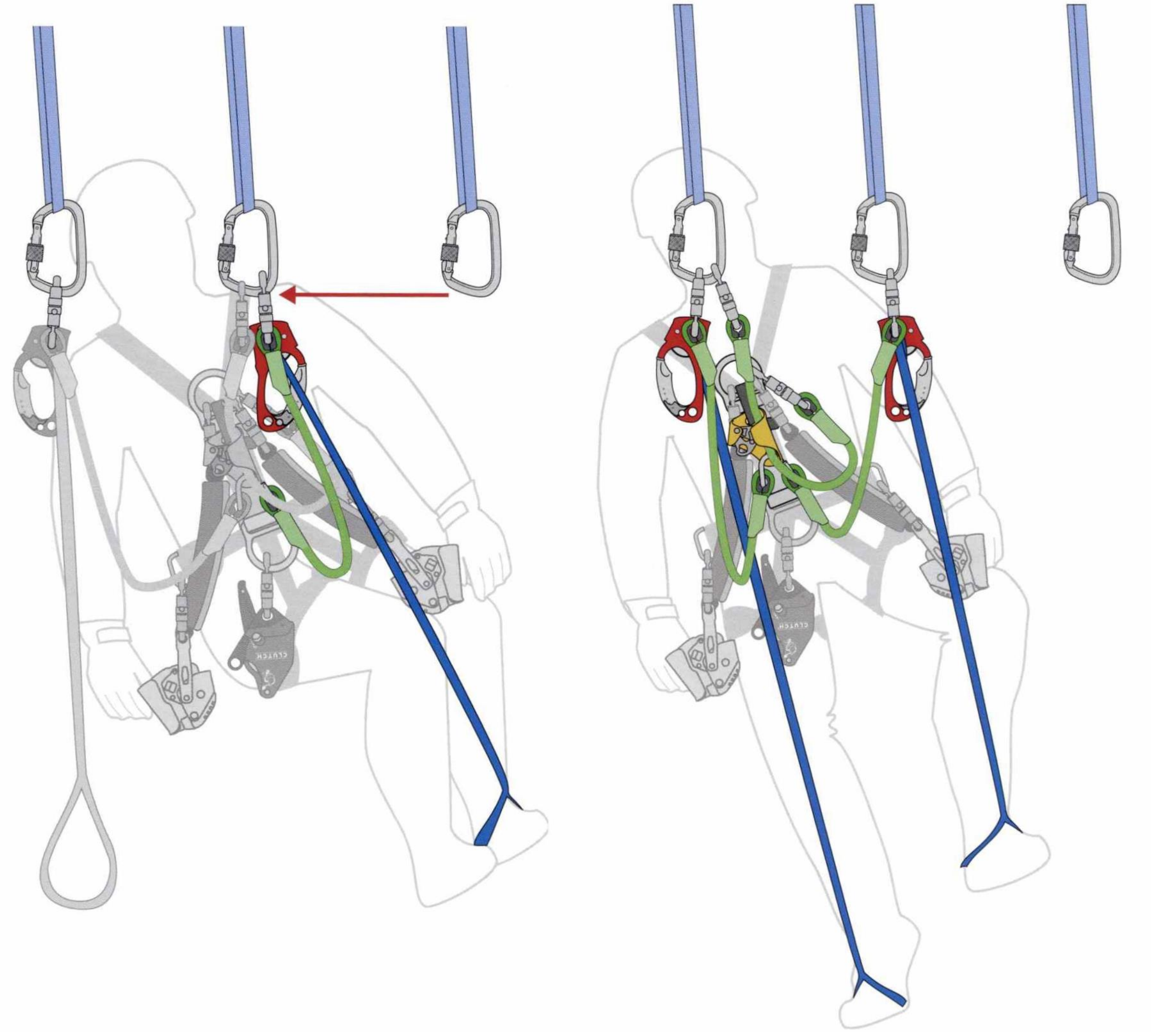
Horizontal aid climbing requires three lanyards attached to your harness, so that one can be moved while the other two provide the two points of attachment. Two of the lanyards are arm's-length long and each will have a foot loop. The third is usually shorter and can be made adjustable by attaching it to your chest ascender as well as to the waist D-ring of your harness. **To maintain two points of attachment at all times only remove one lanyard at a time.**



Step 1

Move the second foot loop out to the next anchor.

Figure 34-16: Horizontal Aid Climbing



Step 2

Sit in your harness and move the first loop to the same anchor as your harness.

Step 3

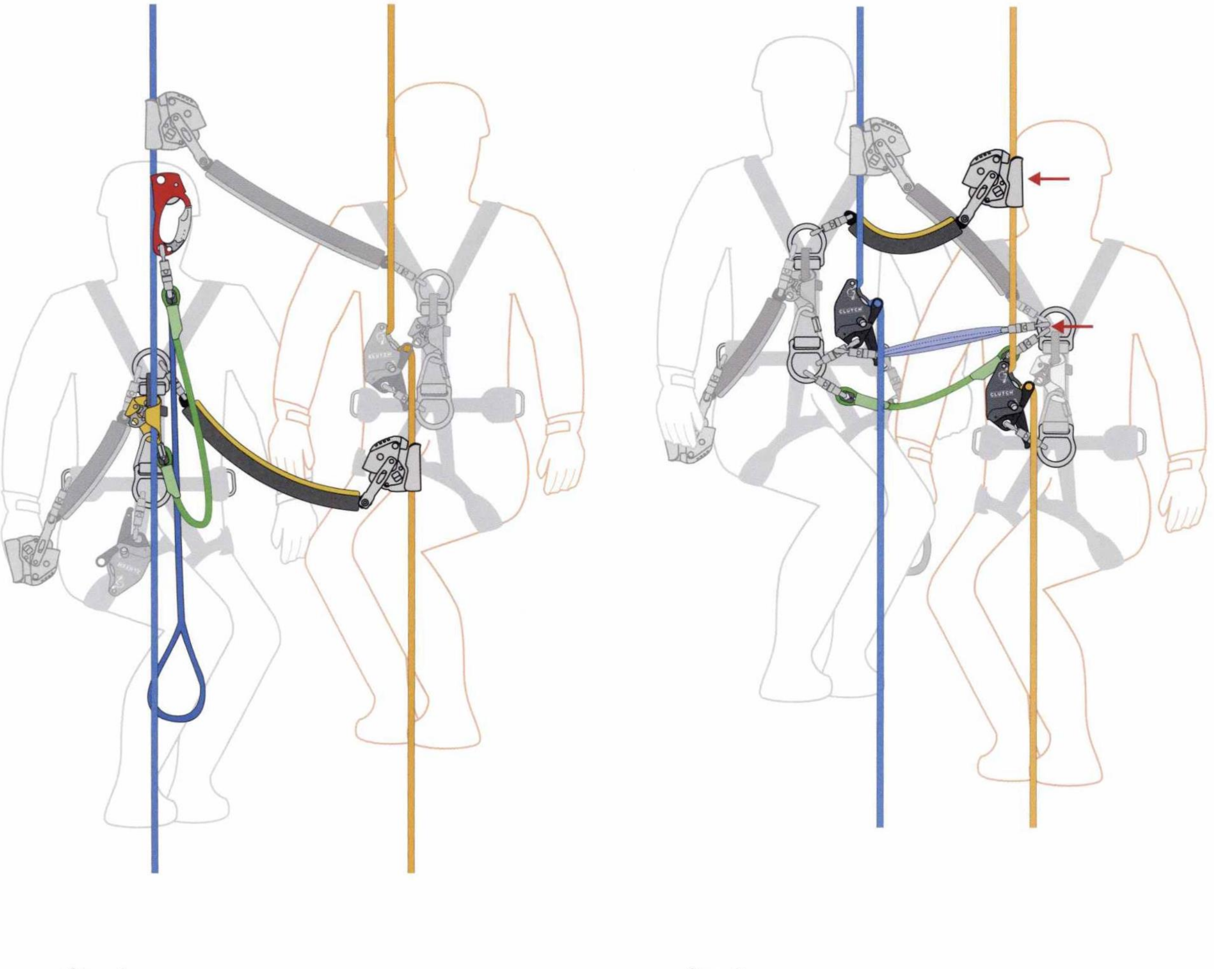
Stand up in both foot loops and move your harness lanyard to the new anchor.

Figure 34-16: Horizontal Aid Climbing

PICK-OFF FROM DESCENT

An important Rope Access Technician skill is the ability to ascend past an incapacitated partner and then lower the partner to the ground. This is a challenging skill, well worth practicing since it builds rope system skills but is also something you will want to do efficiently if the actual need ever arises.

Note: Performing a pick-off rescue past a deviation anchor is an advanced skill. It is not just a matter of combining the pick-off rescue and passing a deviation anchor techniques shown in this chapter.



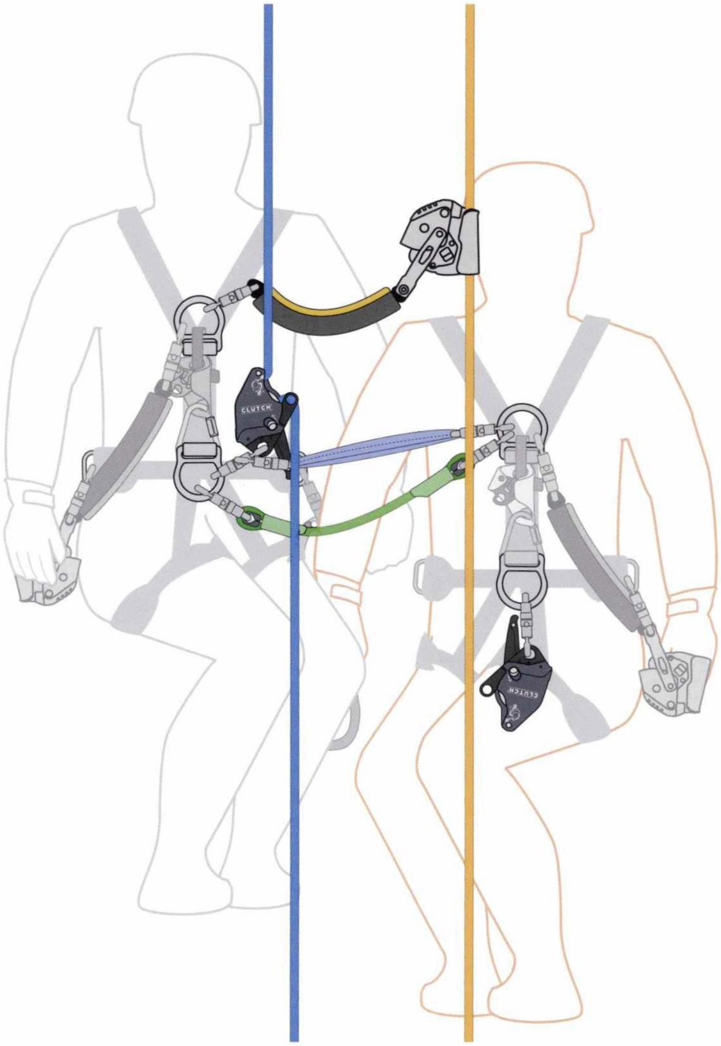
Step 1

Climb up to casualty as high as practical, passing your back-up system past the casualty. Switch into your descending system.

Step 2

Make a short connection between the spine of your descender to the casualty, attach a second lanyard from the rescuer to the casualty to ensure two points of contact, then move upwards on your descender until the short connection between the rescuer and the casualty is taut.

Figure 34-17: Pick-Off From Descent



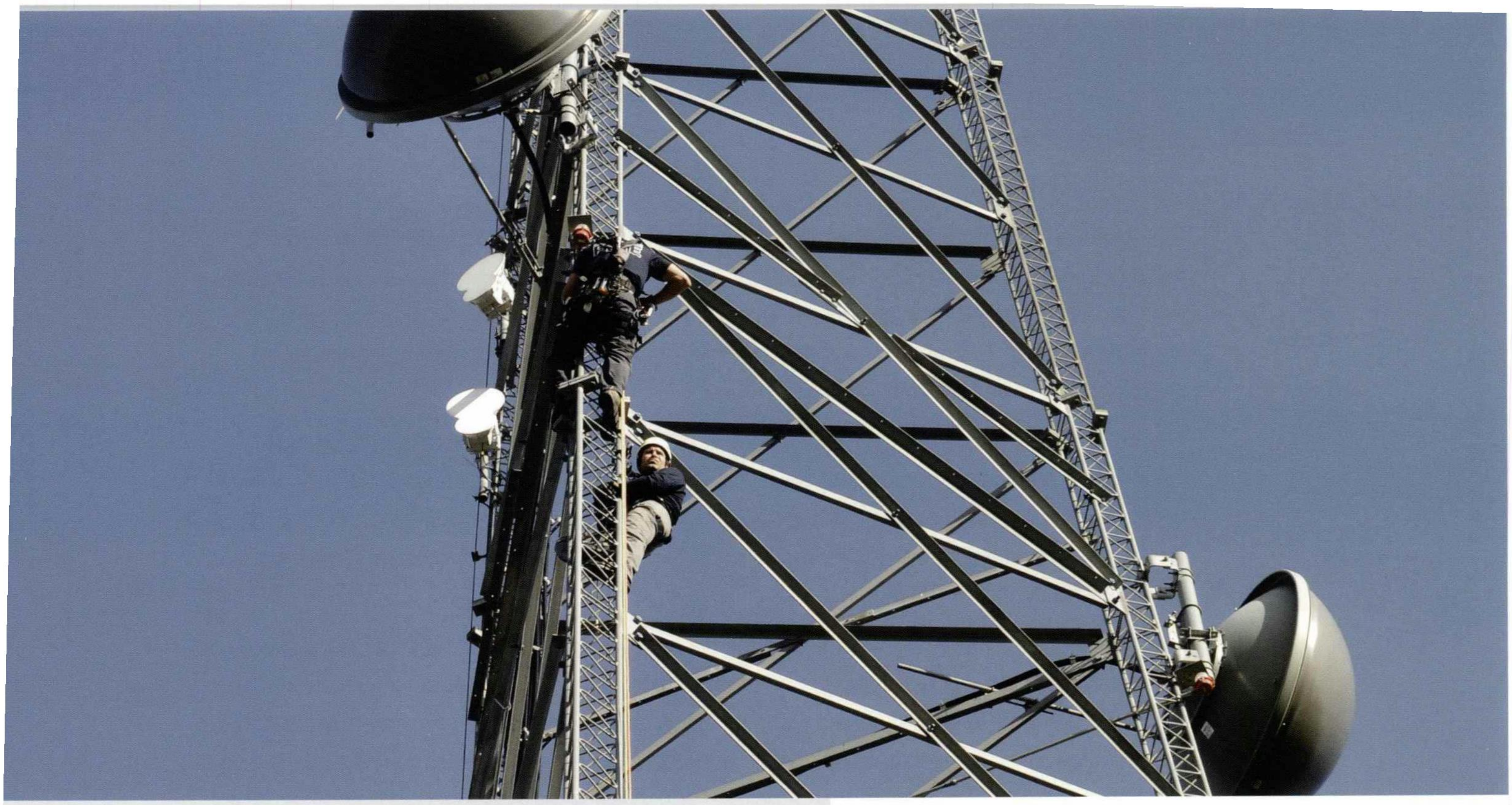
Step 3

Remove the casualty's back-up system. Using the casualty's descender, lower fully transferring the load onto your system. Remove the casualty's descender. Connect a carabiner to add friction onto your descender if necessary* for a two-person load. Descend to the ground.

*The CLUTCH does not require added friction for a pick-off rescue.

Figure 34-17: Pick-Off From Descent

Notes



PART
08
Special Applications

CHAPTER
35
Antenna, Tower & Caged Ladder Rescue

LEGEND: Anchor Grip Load

TERMINAL LEARNING OBJECTIVE

The student will learn how to climb and perform rescues from manmade structures without conventional means of access.

ENABLING LEARNING OBJECTIVES

1. Demonstrate the methods used for a protected climb on a structure
2. Climb a tower or similar man made structure using a climbing belay or bypass lanyard
3. Describe the process to be used if the structure was taller than your standard rope lengths

Rescues from antenna and power transmission towers, cranes and caged ladders are becoming more common due to both the increase in their number and better fall protection regulations. There are far too many variations to the construction and location of these structures for us to cover them all here, but we will give you some general guidelines and specifics on a few of the more common types.

Whenever possible, we suggest that you work the rescue systems from the ground or at least from a stable platform area. It takes time and skill to climb a tower, and fewer people at elevation will not only expedite the operation but will place fewer rescuers at risk. Obviously that would not be possible if the subject were 1,000 feet up, but most cell, water and transmission towers are less than 150 ft high.

After arriving on the scene and sizing up the situation, including the location of the subject and the distance from the ground, the first rescuer begins to climb to the subject's location. The rescuer is wearing a harness, has a radio for communications with the ground team and has a rope long enough to reach from above the subject to the ground. This ***drop line*** can be a small diameter rope (8 to 9 mm) carried in a bag to reduce the weight carried by the climber. When at the subject's location, the rescuer can use the drop line to pull up a rescue line, a complete rescue system or any other equipment that was too heavy to carry.

Depending on the situation, the rescuer will most likely need some sort of fall protection system. This could be the climbing device for the fall protection equipment installed on the structure, a bypass lanyard, a lead climb belay system or even a pole strap. If the subject was not wearing a harness, the rescuer should also carry a CMC Lifesaver Victim Harness and lanyard to secure the subject to the structure and later attach the subject to the rescue system.

For example, our subject is a person climbing a water tower with a caged ladder. Perhaps a foot slipped, and the subject is hanging on, unable to move up or down. Rescuing this subject is essentially the same on a ladder without a cage, but without the access issues caused by the presence of the cage.

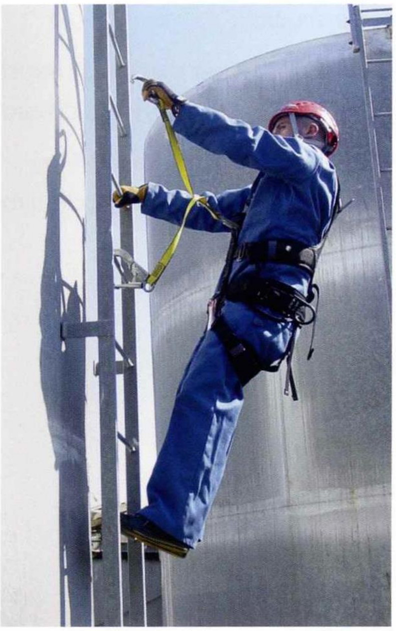


Figure 35-1: Bypass Lanyard

The rescuer climbs to and attaches the subject to the ladder. This step might seem unnecessary for someone who is stuck in a ladder cage, but as with other rescues, the subject might have used all their strength to hang on until help arrives and you do not want to lose the subject. After securing the subject, the rescuer would do a preliminary assessment and relay that information to the team on the ground. A second rescuer may be needed to assist with applying the harness and with the assessment. When the subject is secured to the ladder, a rescuer continues above the subject approximately 10 ft (3 m) to a good anchor point. Passing another person in a ladder cage can be difficult and it might mean that rescuer will have to climb the outside of the cage to get above the subject. Carrying a bypass lanyard gives the rescuer the flexibility of climbing safely outside of a ladder cage as well as providing fall protection while climbing the ladder itself.

While the rescuers are climbing, the ground team rigs the anchors for the main and belay lines, keeping the path of those ropes in mind. They also prepare the change-of-direction pulleys that will be attached above the subject. The ground team adds the anchor straps, carabiners and rescue ropes to the pulleys, doing everything possible to reduce the work for the rescuers above.

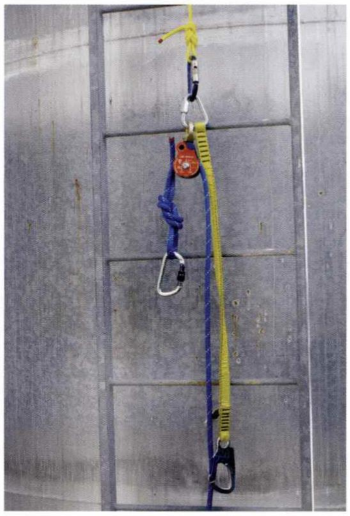


Figure 35-2

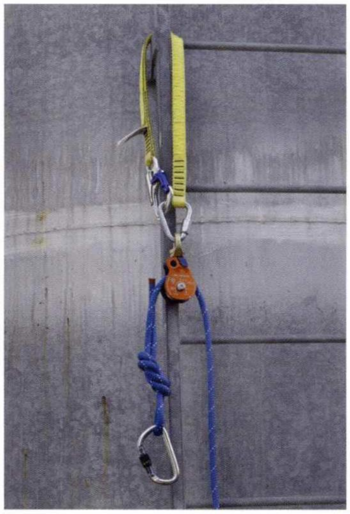


Figure 35-3

Once above the subject and back inside the ladder cage, the rescuer secures one end of the drop line and throws the bag to the team below. The ground team attaches a change-of-direction pulley with the main line (for the lowering) threaded through it. A figure 8 loop is tied into the end of the main line. Since the anchor straps and carabiners are already attached to the pulley, the rescuers can just pull the pulley up and connect the main line system to the structure. The end of the main line with the figure 8 loop comes up with the pulley and the other end stays with the ground team (see Figure 35-2 and Figure 35-3).

Once the change-of-direction pulley is anchored, the rescuers feed the end of the rope with the figure 8 loop down the cage to the subject, routing the rope to avoid sharp edges or other obstructions. The same process is then repeated for the belay line, which is pulled up with the drop line. The belay line should be anchored to a different point on the ladder or structure than the main line.

Once the change-of-direction pulleys for the main and belay line are installed, the top rescuer climbs the end of the lines down and attaches them to the subject's harness. The slack is pulled out and the subject's safety line is disconnected from the ladder. If a second rescuer is available they can downclimb and guide the subject who will be lowered by the ground team, keeping his legs and arms free of the ladder and cage. Depending upon the height and the configuration of the ladder, there may be intermediate landing platforms where the subject can be moved outside the cage so that there would be fewer obstructions for the trip to the ground. Once the subject is on the ground the ropes can be untied and pulled down and the change-of-direction pulleys and anchors can be lowered with the drop line.

RESCUES FROM HEIGHTS LONGER THAN YOUR ROPE

For rescue situations where the subject is too high for the available rope lengths, either a knot passing or a multi-pitch operation must be used. Those systems require more rescuers on the structure but the procedure is similar. The subject would be lowered down secured, the lowering system would be moved down or a second system constructed and then the process would repeat itself as many times as necessary. Knot passing is a relatively simple operation for the team on the ground, but when the knot reaches the change-of-direction pulley above the subject, it becomes a little more difficult. If knot passing is anticipated, a knot pass pulley should be used for the change-of-direction on the tower and a rescuer stationed there to assist the knot through the pulley.

In cases where the tower is tapered it may be easier to guide the subject through the legs and into the interior of the tower where there are fewer obstructions. A guiding line or skate block could also be used to manage the patient, but that might add unnecessary complexity to the operation.

For tower cranes and other locations with adequate work space at elevation you could build and operate the lowering system from above, but it is a trade-off between the time and effort it takes to get personnel and equipment up compared to an easier-to-rig system.

RESCUE FROM A FALL ARREST SYSTEM

Rescue of persons who have fallen onto their fall arrest systems is performed in a similar manner to the previous rescues. They are already wearing a harness but they still need to be connected to the lowering system and disconnected from their fall protection lanyard. Depending upon the height and available rope, the lowering system is built either above or below the subject. If one is available, a SureClip™ pole can be used to connect the main and belay lines to the subject's dorsal attachment point. A vector raise or a load tender piggybacked on the lowering line is used to raise them enough to disconnect the lanyard and they are lowered as before.

Electrical utilities teach pole-top rescue where, after the subject is attached to the lowering line, they cut their pole strap. That is much easier said than done and we have found that raising the subject slightly to take his weight off the strap and disconnecting it with the clip is much easier, not to mention safer, than using a sharp knife around loaded ropes.

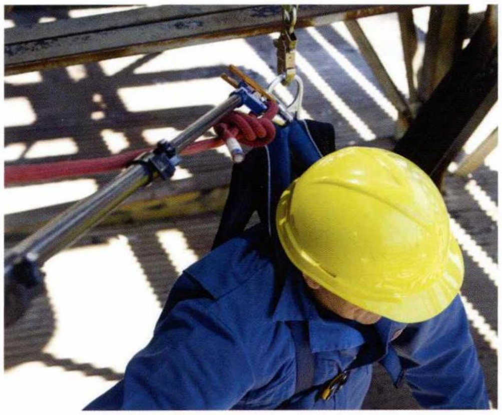


Figure 35-4: Using a Sureclip Pole to attach a line to a fallen worker

PART
08
Special Applications

CHAPTER
36
Escape & Bailout

LEGEND: Anchor Grip Load

TERMINAL LEARNING OBJECTIVE

The student will describe how to use the various kinds of firefighter escape systems.

ENABLING LEARNING OBJECTIVES

1. Describe the different types of escape descent devices
2. Describe the factors that must be considered for an escape anchor

Rappel kits consisting of a small diameter rope, a matching descent control device and an escape harness or belt to exit an elevated location have been in use by firefighters, law enforcement and military special operations for many years. They are also being carried by tower and wind turbine workers as a backup in case their primary means of descent is compromised. In the fire service, escape kits started out as ***drop lines*** for hauling gear or ***roof ropes***, which also provided a rappel line for firefighters working on top of a structure. The concept today has become more of a use-specific kit carried by each firefighter.

Over the years many firefighter fatalities have occurred due to the inability to escape from an untenable location. With the advances in turnout gear and emergency equipment, firefighters can get further into structures and do so faster than before. Combine this with the changes in building construction; fires are hotter, burn faster and have more hazardous by-products in the smoke. The use of lightweight trusses and wood truss floors have made structures more susceptible to a quicker collapse. An escape descent or bailout may be the only life-saving choice for a firefighter facing a rollover, flashover, backdraft or smoke explosion.

An ***escape*** descent or ***bailout*** is a high-risk maneuver—not because of the equipment or training, but because steps to complete the rigging and to start the rappel are done with great urgency and with a high level of distraction. Choosing a suitable anchor, rigging the anchor, moving to the exit and transitioning the edge are all done in a rush, if not a panic.

As with any activity that must be performed quickly and flawlessly, training, preplanning and practice are the essentials to survival. Training from a knowledgeable instructor will help you decide which escape system works best for you and how to set the system up for the most efficient deployment. Preplanning the steps you will take during an escape expedites the decision-making processes during a real event. Training builds the muscle memory. Start slow by getting a feel for your system, then add gear and speed to the exit. Finish by practicing with full turnouts and on air.

Training and practice descents should always be belayed.

ESCAPE EQUIPMENT

Escape Lines

The NFPA 1983 performance requirements for escape rope and escape webbing are:

- Minimum of 7.5 mm ($^{19}/_{64}$ in) or greater and less than 9.5 mm ($^{3}/_{8}$ in) for rope; minimum perimeter of 25 mm (1 in) for webbing
- Elongation of not less than 1% or more than 10% at 10% of breaking strength
- All fibers used must have a minimum melting temperature of not less than 204°C (400°F)
- For fire escape rope and fire escape webbing additional high-temperature exposure requirements are: minimum time of failure 45 seconds at 600°C while holding 300 lb and five minutes at 400°C while holding 300 lb

The specified melting temperature allows the use of nylon or polyester fibers. High-strength and flame-resistant fibers are also used, some of which have a greater resistance to cutting than nylon and polyester. A mixture of fibers is very common, for instance, a nylon core with a polyester sheath or the addition of a high-strength fiber to the core to increase the strength in a smaller diameter rope. As more technologically advanced fibers are added to the rope, the more the cost of the rope increases.

The use of webbing for escape is becoming increasingly popular since webbing packs into a much smaller bag than rope. The strength specification for a manufactured escape system is 13.5 kN (3,034 lbf).

Considerations for selecting an escape line are:

- Temperature requirement – both during a descent and also while carrying. Some departments find the less expensive nylon or polyester meets their needs; some prefer the higher-temperature flame-resistant fibers.
- Cutting over edge – structure exits vary widely and sharp metal edges and broken glass can risk cutting a small diameter rope when the firefighter puts a load on it. Ideally these edges should be cleaned up as they are also a risk to the firefighter. High-technology fibers may provide a greater resistance to cutting than nylon or polyester.
- Rope diameter – generally larger diameter rope provides more strength and tolerates more practice descents than smaller diameter rope. If the firefighter's grip on the rope is a significant part of the control of the descent, such as with a figure 8, then the larger diameter rope will help. The advantage to the smaller diameter rope is the reduction in rope weight and bulk for the same length of line.

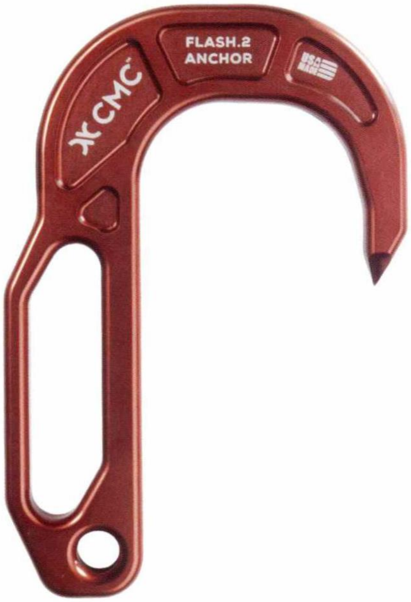
Escape Anchors

The NFPA 1983 performance requirement for an escape anchor is 13.5 kN (3,034 lbf). Some escape anchors may meet the performance requirements for auxiliary equipment, technical use, which is 22 kN (4,946 lbf).

The anchor is a critical element of the escape system and a secure anchor is as much dependent on the device as on the structural element it is connected to. Add to this the location of the anchor point and the time it takes to make any modifications, such as punching through drywall to find a wall stud.

Tools – Wrapping the escape line around an axe or other tool and setting it in the corner of the window will work as an expedient anchor, if there is nothing else. Tension must be kept on the escape line so the tool stays in place. If possible, embed the pick or blade of the tool into the wall for added security.

Carabiners – A carabiner is compact, strong and light. Depending on the gate opening, it can be clipped over a structural element, but the smaller gate opening limits the choice of anchor points strong enough to support the firefighter's weight. The carabiner is very secure where the escape line can be wrapped around an anchor point.



CMC FLASH.2™ Escape Anchor

Hooks – The escape hook fits over a window ledge and the sharp point digs into the wall creating stability. The line can be wrapped around an anchor point with the line tied off to the hook.

Most departments consider anchoring at the window ledge to be a very high-risk last chance maneuver since the load must be kept on the hook to prevent it from disengaging. Even with continuous pressure, the hook could still twist out of position. Training sessions should always be belayed.

Descent Control Devices

Descent control devices (DCD) for escape have evolved significantly since the days of the pompier hook. Besides just wrapping the rope around your body and holding on, today's DCDs include downsized rappel hardware to DCDs specifically designed for escape systems. When selecting a DCD, consider the following features:

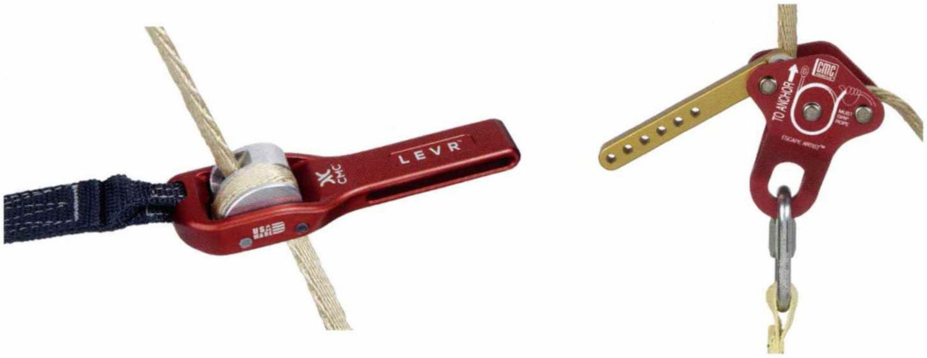
- Auto-stop – Does the device stop the movement or does stopping depend on the grip of the firefighter?
- Hands-free edge transaction – Can the firefighter use both hands to clear the edge or must one hand always remain on the DCD or rope?
- Adjustable friction – Can the friction be adjusted for the descent or is it preset ahead of time?
- Use with gloves – Is the DCD easy to use with the gloves the firefighter is wearing? Does its use require a tight grip on a small diameter rope? Does the control lever require fingertip dexterity?
- Storage – Will the DCD stay rigged while stored in the escape kit bag without tangling or coming undone?

NFPA Standard 1983 has the following performance requirements for an escape DCD:

- The DCD should hold a minimum tensile force of 5 kN (1,124 lbf) without deformation
- For systems, tensile strength of 13.5 kN (3,034 lbf) without failure of the device or the rope

- Passive brake holding test of 1.35 kN (300 lbf) for DCDs with a passive brake feature
- Maximum impact force not to exceed 8 kN (1,798 lbf), 6 inch drop with a 300 lb weight on 24 inches of line

Auto-stop devices include the CMC LEVR™ Escape System. Because this device locks on the rope, supporting the firefighter's weight without the use of his hands, it allows both hands to be used to transition the edge. While descending, the hand operating the lever on the DCD controls the descent, while the other hand grips the rope as a backup safety.



The CMC LEVR™ (Left) and CMC Escape Artist (Right)

Harnesses and Belts

If the incident warrants carrying an escape line and DCD, then you should already be wearing a harness or belt. There are a wide variety of styles and the choice is often determined by some other use, such as a belt for carrying tools, a harness that can also be used for rescues or a belt integrated into a self-contained breathing apparatus (SCBA) harness. A turnout jacket or pants may have an integral belt or harness designed for escape.

While belts are generally not the best choice for fall protection or long-term support, such as that needed during a rescue operation, they are adequate for emergency escape when the firefighter is only suspended for a few moments. If a longer suspension time is required, such as an escape procedure requiring the firefighter to make access to a lower level, then the use of a harness should be considered.

Equipment Bags

The equipment bag should keep the escape gear out of the way during normal operations but allow quick deployment when needed. The equipment bag can be worn on a belt or a harness. It can be suspended from a SCBA or integrated into a turnout pocket. The bag keeps the gear organized for quick deployment and provides some protection from abrasion and heat.

GETTING OUT

The process of an emergency exit from a structure should be planned ahead of time with thought given to equipment set-up, anchor choices and the physical steps that will be taken. All of this should be integrated into the initial training and continuing practice.

A critical planning element is the decision-making process of recognizing the unsafe conditions that determine the need to exit the structure. Education in situational awareness, warning signs of hazardous conditions and department safety policy is all part of the process.

Pre-Rigging the System

There are two primary schools of thought on how to pre-rig an escape system. Some kits are set up so that the descender is connected to the harness. An extension on the harness or a tether allows the descender to reach around your side and fit into the bag storing the system. If properly set up, the bag can be opened, the attachment to the anchor point made and the system is ready to go. The advantage is a very fast exit as long as all the parts come out of the bag without being tangled or cross loaded.

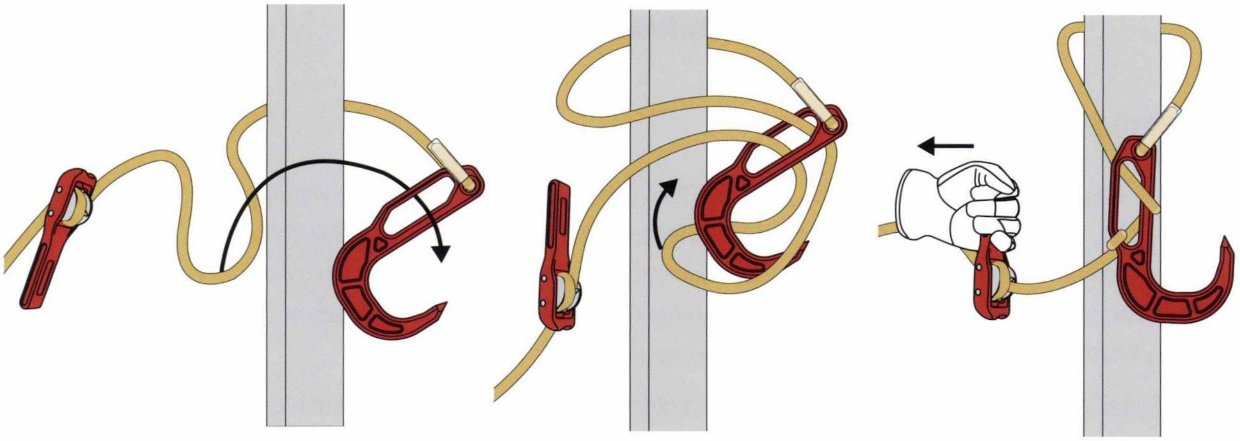


Figure 36-1: Tying-Off the Flash.2 Escape Anchor

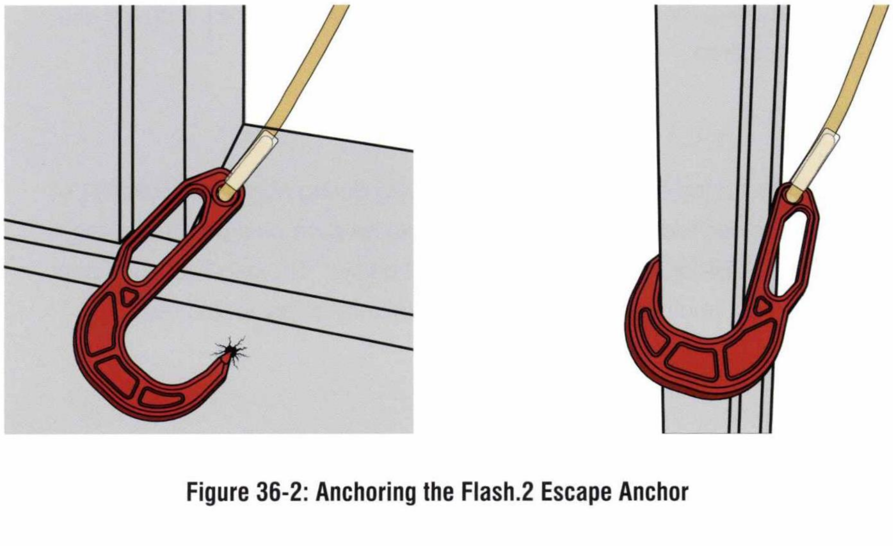


Figure 36-2: Anchoring the Flash.2 Escape Anchor

The other option is to connect the descender to your harness or belt when you need it. Given the time it takes to set a safe anchor, the extra moment necessary to clip the carabiner on the descender to your harness should not slow down the escape by very much. By keeping the entire escape system in a storage bag, the firefighter has more options as to where to carry the bag, so it stays out of the way, such as below the SCBA or on the back of a belt.

With either system, a quick check of the components should be made before going out the exit. Look for cross loading of carabiners, any knots or tangles that could jam in the descender or twists in the system that could make it difficult to control the descent.

Anchor Points

Connecting the escape line to a solid object is the most uncontrollable step in the process of getting out of the structure. Until the need arises, you have a very limited idea of what will be available that will be compatible with your anchor device and will support your weight.

The choice of an anchor point may be across the room: a door, large piece of furniture or structural element, such as a pipe or fixture in another room or stairwell.
An anchorage on the side of the room will push the escape line into the corner of the window, but that is less important than making sure you have a strong anchor point.

Hook-style anchor devices are designed to connect over the sill plate of a window. Check to make sure that the sill plate will support your weight. Another choice at the window is wrapping the escape line around an axe or other tool and placing it in the corner of the window frame. This is a secure anchor as long as your weight holds the tool in place.

SAFE USE OF AN AUTO-STOP ESCAPE DEVICE

Safe use of a descent control system for emergency escape requires competence operating the device as well as basic rappel skills. CMC encourages training from a qualified instructor and practice in setting an anchor, exiting a window, and operating the descent control device. Use an independent belay for training and for practice.

Using the CMC LEVR™ Escape System

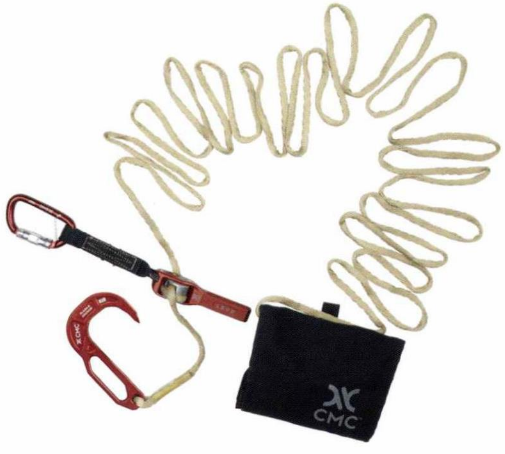


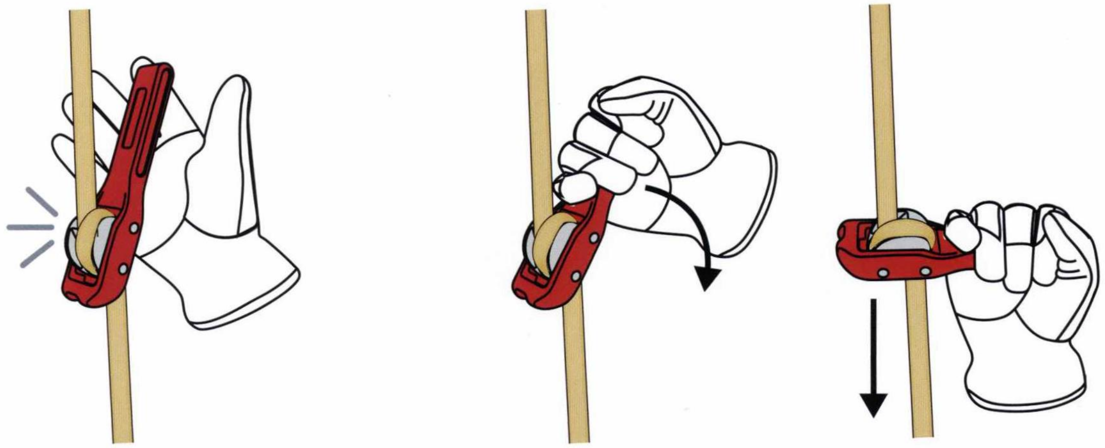
Figure 36-3: CMC LEVR Escape System

The CMC LEVR Escape System comes complete with the LEVR descent control device, fire escape webbing, Flash 2 Escape anchor, Nomex® carrying bag and CMC Pro-Tech auto-lock carabiner. The fire escape web is installed in the LEVR system at CMC.

The LEVR is an auto-stop device which frees both hands for exiting the window. After setting a secure anchor, grasp the handle of the LEVR in one hand and the web in the other. Pull the handle towards you to move across to the exit window. At the edge, clear anything at the opening that might damage the web.

If possible, extend the LEVR over the edge of the opening. The LEVR is designed to minimize the risk of hanging up on the edge if it is loaded with your weight before clearing the window edge. The LEVR is an auto-stop device, allowing both hands to be used to exit if necessary.

Outside the window, grip the handle in one hand and the web in the other. Pull the handle towards you to control your descent. The speed of descent is controlled by how much you pull the handle towards you and your grip on the web. To stop, release the handle.



Auto-Stop

Controlled Descent

Figure 36-4: Descending with the LEVR

Using the CMC Escape Artist™

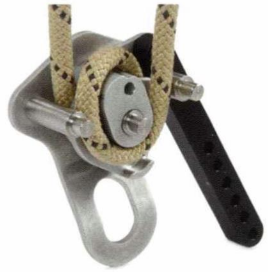


Figure 36-5: Proper Reeving of the Escape Artist

The escape rope must be pre-rigged into the Escape Artist so that it is ready for use when needed. A diagram for reeving the rope through the device is permanently marked on the side plate. It is essential to the function of the Escape Artist that the rope be correctly reeved (see Figure 36-5).

The Escape Artist is designed to allow both hands to be used to exit a window or other opening in the structure. A safe bailout requires a moderate amount of preplanning, including enough time to set a secure anchor. After setting the anchor, a slight squeeze on the control lever will let out rope as necessary to move to your exit location.

At the opening remove any edge material that may damage the escape rope and make sure that the harness carabiner, Escape Artist and any other equipment clears the edge without damage or hanging up. Both hands can be used to safely exit the structure and lower your weight onto the system.

Once your weight is on the system, place your control hand over the Escape Artist and your other hand on the untensioned (running) end of the rope. Slowly squeeze the control lever to initiate your descent. Varying the pressure on the control lever controls the speed of the descent, which is backed up by the grip of your other hand on the running end of the rope. To stop, release the lever.

Notes

PART
08
Special Applications

CHAPTER
37
Snow & Smooth Slope Evacuations

LEGEND: Anchor Grip Load

TERMINAL LEARNING OBJECTIVE

The student will describe the differences for anchoring, litter tending and forces in the system when working on snow or other smooth terrain.

ENABLING LEARNING OBJECTIVES

1. Describe the method for litter tending on snow
2. Describe the conditions where a belay might not be considered essential to the safety of the system

The ability to slide the litter on snow significantly reduces the load placed on the rope rescue system. Because of the reduced load, much lighter-duty equipment can be used while maintaining the same system safety factors. While our primary experience with these systems is on snow, they can also be used on stairways, aerial ladders or sloping hillsides that provide a smooth, sliding surface.

The significant difference between a snow system and a low angle system is that the tender, or tenders, are not lifting the litter. The litter remains on the surface and slides in the direction of travel. By removing the effect of the tender's weight from the litter, the lowering or the raising system only has to resist or lift the litter's tendency to slide.

Tenders

The number of tenders required depends on the steepness of the terrain. The tenders connect to the litter with a long tag line that allows them to walk beside the litter. If the angle is fairly flat, the tenders move to the front of the litter and pull. In this case, two tenders may be better than one, both to help pull and also to balance out the pull.

The tenders are also a component of the belay to the litter. If there is a main line failure, then the tenders drop into an ice-axe arrest or plant their ice axes as anchors to stop any movement. On steeper terrain, two or even four tenders may be desired for an effective belay.

On terrain where directional stability is an issue, such as keeping the litter on a ridge line, four tenders are used. Two are positioned in front to steer the litter and two behind to keep the litter in line with the direction of travel.

Main Line

Because of the lighter loads encountered, a smaller diameter rope can be used for the main line. This is important for winter operations since the rescuers are usually hiking to the rescue and carrying cold weather survival gear for themselves and the subjects.

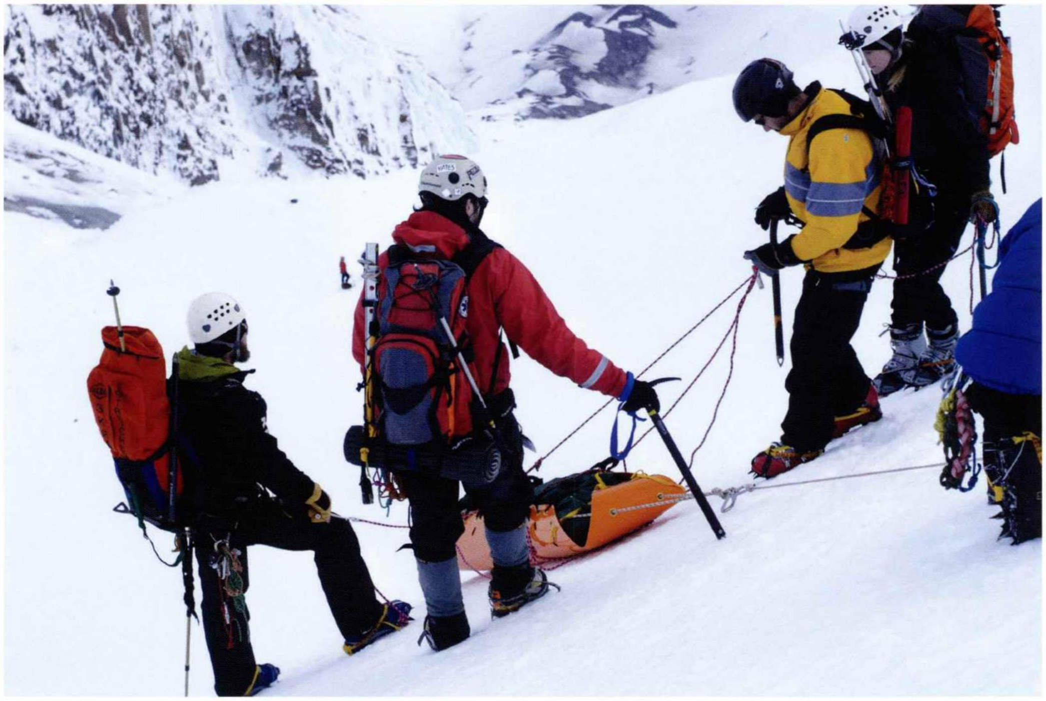
A descent control device that is designed for single-person loads, such as a micro-rack, CMC 3D, or a Petzl GriGri could be considered. The GriGri or similar device has the advantage of braking the descent or on a raising acting as the ratchet. The loss of efficiency of not having a change-of-direction pulley at the anchor is less a concern due to the decreased load; the only concern is the force needed to slide the litter upward.

Belay

In most cases the angle of the slope and the snow conditions will allow the tenders to arrest a main line failure. For hard snow or very steep slopes a separate belay line should be added. This may be necessary for other sliding surfaces where the tenders are able to walk beside the litter but may not be able to anchor themselves to hold the litter.

Litters

A litter that provides a smooth bottom surface will be needed. The Traverse ADVANTAGE, Junkin Plastic or Cascade Advance are good choices since they have a stiff, smooth bottom and a full frame for securely connecting the main line, belay line and the tender's tag lines. A SKED litter can also be used.



Portland Mountain Rescue developed their Hogsback Kit for a specific ridgeline on Mt. Hood on which they frequently evacuate patients. The kit combines a small diameter rope, mini brake bar rack and four tenders walking beside the litter.

Notes

SUGGESTED EQUIPMENT LISTS

The following is a minimum equipment list for the typical fire department or industrial rescue team. This equipment will let the team safely complete basic rescues. Note that for organizations using the CLUTCH, MPD or similar devices, less rigging equipment is required. The rope length is not specified since it is dependent on the elevation of the rescues that your organization will encounter. Additional rope, web, carabiners and other hardware will provide the capability to handle more difficult rescues.

System Rigging Equipment

	CLUTCH	MPD	Other Devices
NFPA, G-rated Life Safety Rope	2	2	2
Rope Bags of size to fit ropes	2	2	2
Carabiners, NFPA General Use	7	7	11
Carabiners, NFPA Technical Use	1	1	1
Carabiners, non-locking			2
Anchor Plate			1
Pulleys, NFPA General Use	3	3	5
MPD		2	
CLUTCH	2		
Brake Bar Rack			1
Anchor Strap, 5 ft (1.5 m)	2	2	2
Anchor Strap, 7 ft (2.1 m)	2	2	2
Delta Quick Links	4	4	2
1 in Tubular Web, 12 ft (3.7 m)	2	2	2
1 in Tubular Web, 20 ft (6.1 m)	2	2	2
8 mm Prusik Loops, short, 56 in (1.42 m)	2	2	1
8 mm Prusik Loops, long, 70 in (1.78 m)			4
Load Release Strap			1
Equipment Bag	1	1	1

Edge Protection Kit

Ultra-Pro 2 Edge Protector	1
Edge Guards	4
Edge Pad, XL	1
6 mm Accessory Cord, 20 ft (6.1 m) for anchoring edge protection	6
Gear Bag	1

Litter Kit

Litter	1
Litter Shield	1
Litter Harness (for the type of evacuations anticipated)	1
Etrier with Tie-in	1
Carabiners, NFPA General Use	4
Carabiners, NFPA Technical Use	3
CMC or Gibbs Ascenders	2
Litter Straps	4
1 in Tubular Web, 12 ft (3.7 m)	3
1 in Tubular Web, 20 ft (6.1 m)	2
Litter Pack	1

Rope Rescue Technician Personal Kit

Helmet	1
Gloves	1
Eye Protection	1
Hearing Protection	1
Rescue Harness	1
Rescue Chest Harness (optional if rescue harness is not a full-body harness)	1
Carabiners, NFPA Technical Use	6
Headlamp	1
Descent Control Device	1
8 mm Prusik Loops, short, 56 in (1.42 m)	1
8 mm Prusik Loops, long, 70 in (1.78 m)	2
One-Inch Tubular Web, 12 ft (3.7 m)	2
Gear Bag	1

Subject Kit

Lifesaver Victim Harness™	1
Carabiners, NFPA Technical Use	2
Pick-Off Strap	1
8 mm Prusik Loops, short, 56 in (1.42 m)	2
Helmet	1

CMC ROPE LOG

Date in Service: ____________ ROPE NUMBER ____________

Length: ________ (ft) Diameter: _____ (in) Rope Color: __________ Bag Color: ________

Manufacturer: ____________ Model: ____________ Tensile Strength: __________

	Date	Incident/Location [a]	How Used [b]	Possible Damage [c]	Inspection Results	Sign In
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
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16						
17						
18						
19						
20						

a. Include such activites as operations, trainings, inspections and washing.

b. Detail use of the rope, such as for rappel, rappel rescue, main line and system belay.

c. Did something happen that may have damaged the rope, such as rockfall, impact load, severe abrasion or other abuse?

This form can be downloaded at cmcpro.com/forms

HARDWARE INSPECTION & MAINTENANCE LOG

ITEM ______________________ #________ DATE IN SERVICE ______________________

BRAND/MODEL ______________________________ STRENGTH ______________________

Date	How Used or Maintained	Comments	Name

This form can be downloaded at cmcpro.com/forms

SI UNITS OF MEASURE

The International System of Units (SI) is the global system of measurement. It is informally referred to as the metric system in the United States. Standards writing bodies, such as ASTM and NFPA, use this system when they establish the MBS for rescue equipment. Because SI units are used on equipment, having a working knowledge of this system is important if the rescuer is to understand load ratings and safety factors of rescue equipment and systems.

SI is based on the decimal system (factors of 10) and uses a prefix to designate the order of magnitude of the base unit. For example, the prefix kilo means 1000. 1000 newtons = 1 kilonewton (kN) or 1000 grams = 1 kilogram (kg). Milli means one one-thousandth. A millimeter (mm) = 1/1000 of a meter. Centi means one one-hundredth. A centimeter (cm) = 1/100 of a meter.

The following definitions relate to equipment and rescue system strength ratings:

Weight is a force – The weight of a body is a product of its mass and the acceleration due to gravity.

Mass is the quantity of matter in a physical body. It is a measure of a body's resistance to acceleration. Mass does not change.

Pound (lb) is the US value for mass.

Kilogram (kg) is the SI value for mass (equals 1000 grams).

Pound-force (lbf) is the US value for force.

Newton (N) is the SI value for force. It is the force that, when applied to a 1 kg mass, gives an acceleration of 1 m/s^2.

Kilonewton (kN) is 1000 newtons. It is approximately 220 pounds.

Acceleration due to gravity varies over the earth between 9.77 and 9.83 m/s^2. For the purpose of determining forces in rescue systems rounding up to 10 m/s^2 will simplify the process while adding a small margin of safety to make up for errors that might be made in estimating the load.

Load can mean either mass or force, depending on its use. A load that produces a vertically downward force due to gravity may be expressed in mass units (100 kg load). Any other load is expressed in force units (such as 1 kN).

SI UNITS OF MEASURE (CONTINUED)

Conversion Factors from US Units to SI Metric Units

For this Quantity	To Convert from US Units	Multiply By	To Obtain SI Units	Multiply By	To Obtain US Units
Mass	pound-mass (lb)	0.45359237	kilogram	2.204655	pound (lb)
Length	inch (in)	25.4 (exact)	millimeter (mm)	.039370	inch (in)
	foot (ft)	0.3048	meter (m)	3.2808	foot (ft)
Speed	feet per second (ft/s)	0.3048	meter per second (m/s)	3.2808	feet per second (ft/s)
Acceleration	feet per second squared (ft/s^2)	0.3048	meter per second squared (m/s^2)	3.2808	feet per second squared (ft/s^2)
Force	pound-force (lbf)	4.448222 (4.4482216152605) .0044482	Newton (N) (kg • m/$s^{2)}$ kiloNewton (kN)	.02248	pound-force (lbf)

Metric Rules of Thumb

A rule of thumb is an easily learned and easily applied procedure for estimating a value. For those of us not raised using the metric system, the following values have been rounded to simplify the process.

Mass = 2.2 lb = 1 kg

Acceleration of Gravity = 10 m/s^2

(For exact conversion factors use the table above)

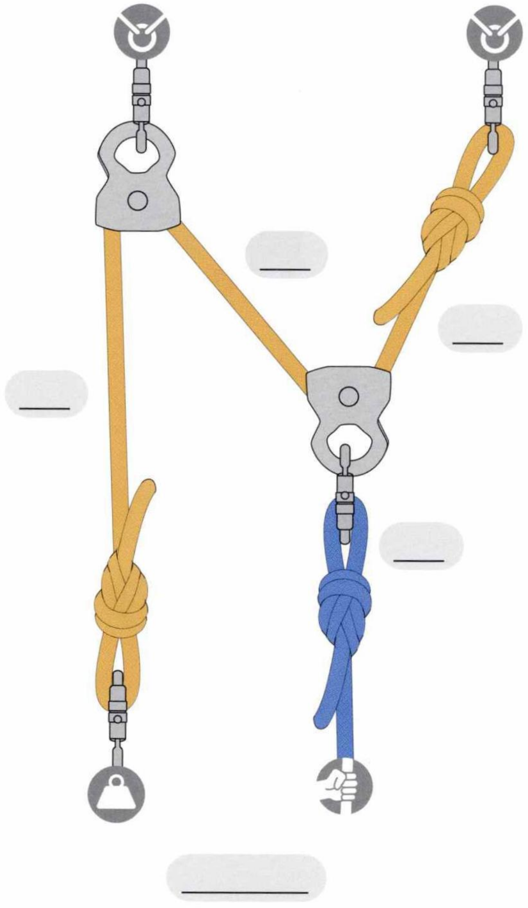
To use the metric rule of thumb to determine the force placed on a rescue system assume that every person has a 100 kg mass (220 lb divided by 2.2 = 100 kg). Multiply that by the acceleration of gravity, 100 kg x 10 m/s^2 = 1000 N or 1 kN.

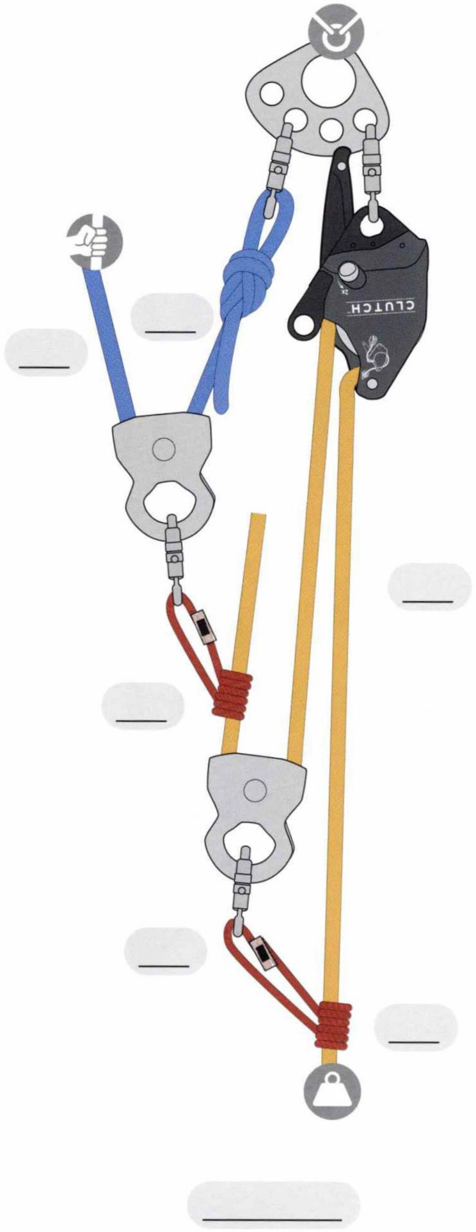
One rescuer on the system = 1 kN

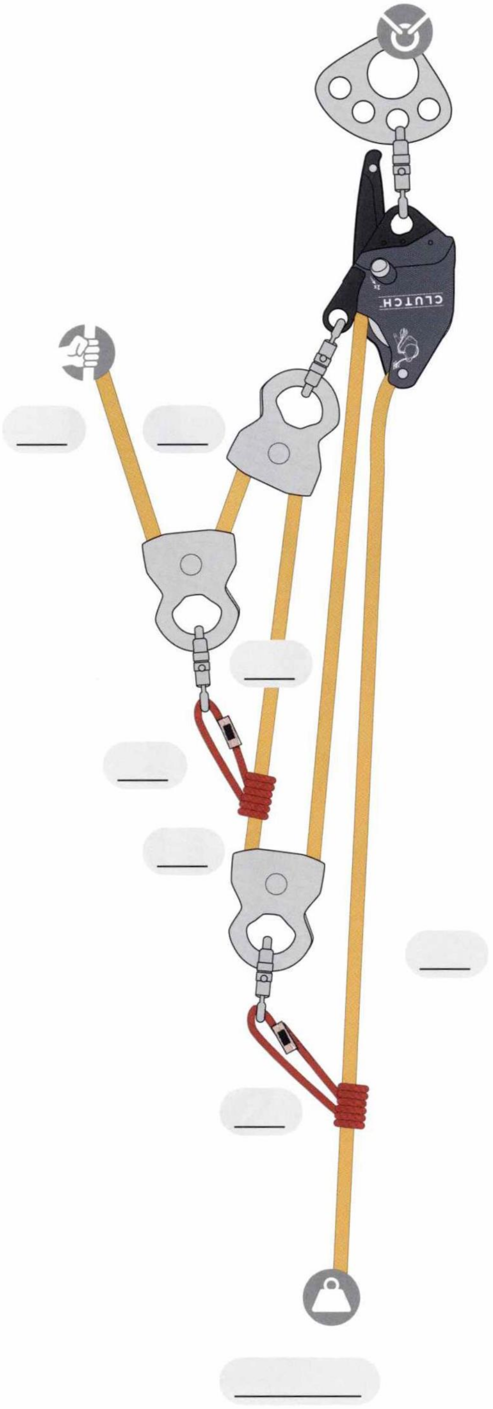
One rescuer and one subject on the system = 2 kN

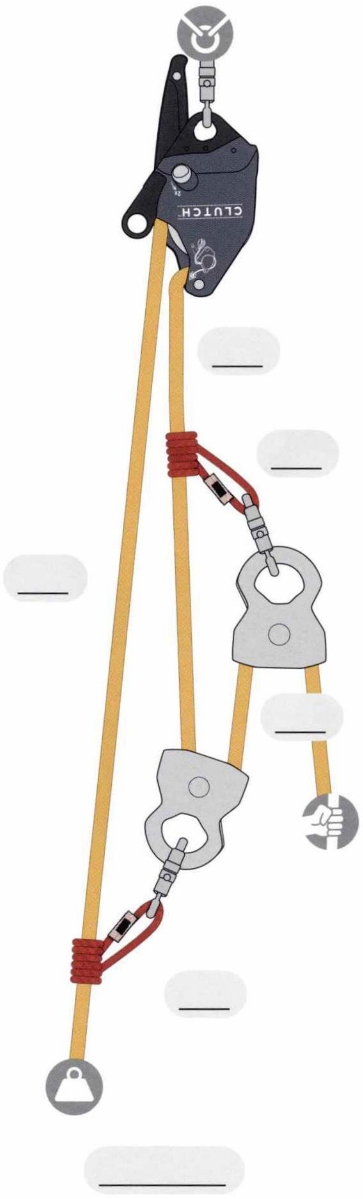
T-METHOD PRACTICE

Use these systems to practice with the T-method for determining mechanical advantage. For the answers, go to cmcpro.com/toolkit and look under the CMC Rope Rescue Technician Manual product listing.






CLUTCH


CLUTCH

ROPE CONTAMINATION TESTS

For those of you who are fairly new to ITRS, the staff of CMC has presented the results of various rope testing projects at previous Symposiums. Those tests were prompted by questions asked by students in our classes and to our customer service staff. While we could have speculated, it was our desire to have real world "we know because we tested it" answers. Those papers are available online under the titles of:

"How Much Does It Really Matter?"

"Don't XXX on That Rope"

"You Asked, We Tested"

Some of the results of those tests are summarized on the following page. That testing was performed primarily on 100% nylon rope. Since that time we have seen the introduction and growing popularity of 100% polyester rope. Following that came the same questions that we had been asked before-"What will? do to my rope?"

The characteristics of polyester are well known so we thought we knew the answers, but we had some surprises before. To be sure we answered correctly we decided it was time for a new round of testing.

We tried to duplicate the earlier tests to give a better comparison between the two rope materials. When possible we used the same contaminants and exposed the samples for approximately the same amount of time before breaking them. We did add a few new ones based on questions we had received and in some cases applied the contaminant multiple times to simulate real world conditions such as disinfecting.

The 2013 tests, except where noted, were performed on ½" CMC Static-Pro Lifeline. It is constructed from 100% high tenacity polyester with a published MBS of 9217 lbf. All the test samples were cut from the same spool of rope which was manufactured during the 2nd quarter of 2013. Five samples were tested for each of 23 contaminants or a total of 120 tests (5 control samples.)

The point of the testing is not to make a value judgment between the different rope materials. There are other, more important, reasons to select which rope you will be using for which application. We know that things happen to get spilled on rope and we wanted to be able to intelligently answer the questions when they were asked.

The tests were conducted at different times over several weeks which is why the differences in exposure time. However each batch of 5 samples was tested on the same day. The contaminant was applied to a section, approximately 6" long, in the center of each 15' sample. The samples were wrapped around a 4" bollards and slow pulled using the Cordage Institute test method (CI-1500.) The contaminated section was between the bollards when the sample was tested. In many cases the contaminant evaporated long before the testing was completed. For example: the gasoline and alcohol evaporated within 24 hours while other materials such as the less volatile hydraulic oils were present when the testing occurred and were wrung out of the rope as it was pulled.

Many of the products used are generic in nature. For example the bleach, ammonia, gasoline, diesel fuel, etc. were purchased "off the shelf" and could vary between lot numbers, brands, regions of the country or time since manufacture. For some other contaminants they were what they were and there is no standard. For that reason these tests are not exactly reproducible. You might get slightly different results even if you follow the same methods with the same rope.

	Rope Material: Nylon/Nylon		**Polyester/Polyester-2013 Tests**	
Contaminant	**Exposure Time**	**Strength Change**	**Exposure Time**	**Strength Change**
Water	30 min	-11%		
Water	3 Hours	-23%		
Sanford Rub a Dub	57 Days	No Change		
Bluewater Nylon Marker	57 Days	No Change		
Sanford Magnum Marker	57 Days	No Change	70 Days	+3%
100% Bleach	10 min/14 days	-13	3x/40 days	-20%
10% Bleach/Water	10 min/14 days	-2%	3x/40 days	-7%
Isopropyl Alcohol*	2x 46 days	-7%	49 days	No Change
Duct Tape	40 days	-5%	52 days	No Change
Unleaded Gasoline	38 days	No Change	50 days	+4%
#2 Diesel	38 days	-6%	50 days	+4%
3 in 1 Oil	46 days	-7%	70 days	+3%
WD-40	46 days	-5%	70 days	+3%
Hydraulic Tool Fluid Phosphate Ester (Hurst)#	26 days	-5%	2x 40 days	+3%
Hydraulic Tool Fluid Mineral Oil (Amkus/Holmatro)	23 days	-2%	76 days	+3%
Hydraulic Tool Fluid Diethylene Glycol (Phoenix)	38 days	No Change	51 days	+3%
DEET 100%	11 days	No Change	50 days	+4%
Tobacco juice/saliva	11 days	-9%	66 days	No Change
Ammonia	38 days	-15%	4x over 48 days	-4%
Urine	38 days	-20%	66 days	-16%
Battery Acid	10 min/ 39 days	-49%		
Battery Acid Wipe	14 days	-1%	75 days	No Change
Battery Acid Wipe**	14 days	-56%		
Foam Concentrate Cold Fire	27 days	-14%		
Foam Concentrate Micro Blaze Out	27 days	-3%		
Foam Concentrate Ansulite 3% AFFF Type B	28 days	-6%	51	-3%
Foam Concentrate Ansul Silv-ex Class A	29 days	-14%	40	+8%
Chain Saw Fuel Mix (Craftsman)			51 days	+6%
Roundup (glyphosate)			3x/49 days	-1%
Electrical Tape (Scotch 33-Red)			70 days	No Change
Model Paint (Testors-White)			52 days	+2%

*Isopropyl Alcohol 91% strength on Nylon tests, 70 % on polyester tests

** This test was performed on Polyester over Nylon rope (KMIII)

#Hurst Fluid Genuine Hurst brand on Nylon, Skydrol on polyester (both are described phosphate ester)

Note: We do not recommend you soak your rope in petroleum products to make it stronger. Those small increases in strength are due to the testing process and most consider variances of less than 3-5% not significant. There is no logical explanation for why a marker or paint would increase the strength of a rope.

Cautions and Disclaimer:

- For your continued safety protect your rope from contamination by these or other chemicals.
- Results may change with different brands of rope.
- Different brands of tapes may use different adhesives.
- The length of time the rope is exposed to the contaminant may change the outcome of the test.
- Different brands of markers may use different ingredients. Recipes may vary within the same brand of marker depending upon a multitude of factors.

Recommendations:

Inspect your rope carefully before and after each use.

Keep your ropes clean and stored away from possible contaminants.

Follow the manufacturer's instructions for inspection, cleaning and removal from service.

If in doubt, throw it out!

We Did One Additional Test

1" tubular nylon webbing is often used to secure a patient in a litter and because it can easily become contaminated with blood and other fluids it is subject to multiple decontamination cycles. We tested 5 samples of new webbing using the recommended 10% household bleach and water solution and had an 87% strength loss (4220 lbf reduced to 530 lbf) after 3 cycles over 76 days. While there isn't a lot of force placed on webbing used to tie a patient in a litter if that same webbing were used as an anchor the results could easily be catastrophic. THINK ABOUT IT.

Effect of Disinfecting Agents on Nylon

CMC conducted additional testing on the contamination of nylon products and presented at ITRS 2014. The study was intended to provide data on the effect of disinfection agents on nylon rope and webbing as used in the rescue industry.

The study began with an industry survey to determine the most common products used to wash and disinfect webbing and rescue rope. We also included products used by cavers as the "white nose syndrome" concern required frequent disinfection of their equipment.

The tests used 5 samples of one-inch webbing and explored the post washing tensile strength of the web. Soak time was 10 minutes immediately followed by being hand rinsed twice. (rinse water replaced after each group). Minimum 3-day drying time. Five cycles per group. The ability of the products to clean or disinfect the rope was not measured.

Contaminant	One-Inch Tubular Web
Lysol® IC 1:28	-3%
Hot Water Bath/Immersion – 86°C (176°F)	-2%
Formula 409 (100%)	+1%
Cavicide (100%)	-4%
Chlorox Bleach (10%)	-8%
Chlorox Bleach (100%)	-56%

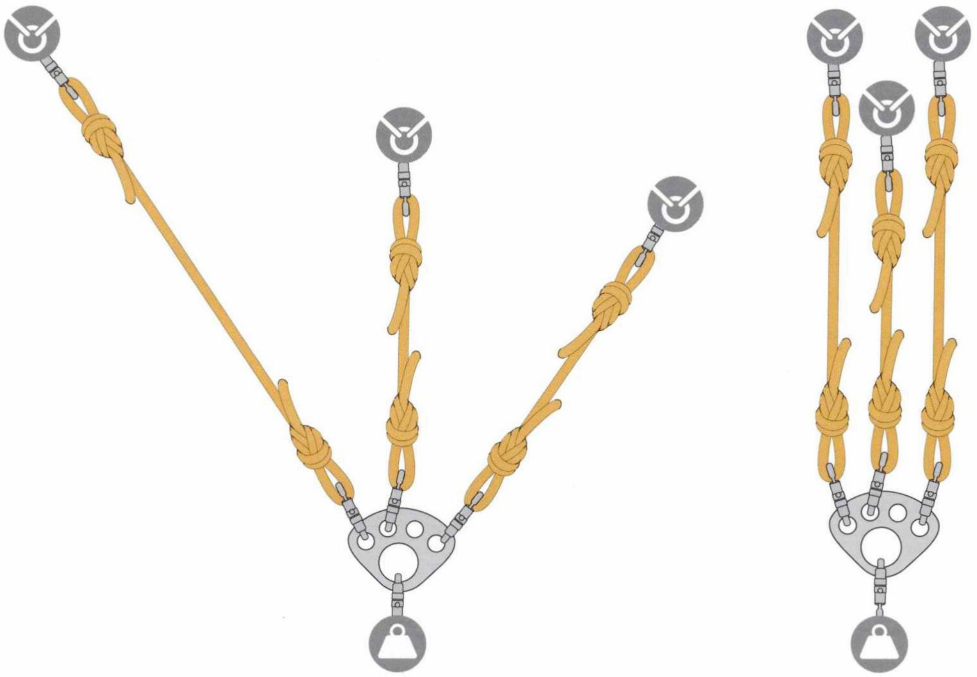
MULTI-POINT ANCHOR TESTS

When rigging a rescue anchor system, finding a bombproof anchor point that is perfectly situated is very rare. The need to build an anchor system that corrects for bad location or spreads the load over multiple weaker points is more the norm.

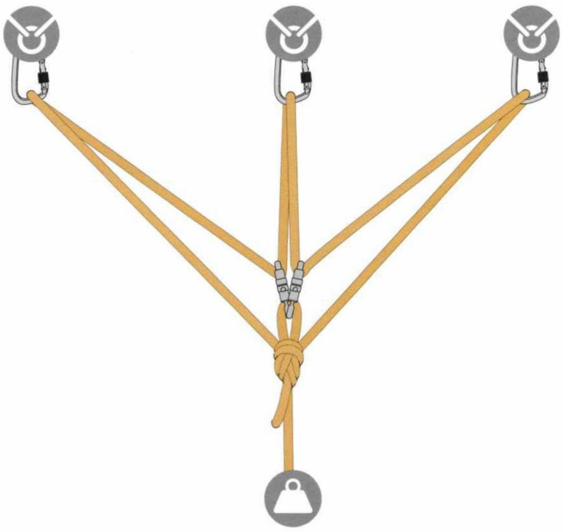
There are two major types of multipoint anchors: load sharing and load distributing.

Load-sharing anchors have fixed length extensions from the various anchor points that connect together to support the load. Two factors determine how much load will end up on each anchor point. Those are the distance the anchor points are apart, which translates into the angle between the different legs, and the rigger's ability to tie the proper length extension for each point. Should one of the anchor points fail, their placement in relationship to the direction of pull will determine the resulting load on the remaining point(s). An ideal three-point load-sharing anchor would be similar to the one on the left. The three parallel legs would each support one-third of the load. More often, the situation looks like the one on the right. The anchor points are far apart, which increases the force on each leg. If each extension isn't tied so the tension is equal to the other two, the increased force is not shared equally among the three anchor points.

Load-distributing, sometimes called self-equalizing, anchors have variable length extensions that, in a perfect world, would allow the load to be equally distributed to all the anchor points. The angle between the anchor points also affects load-distributing anchor systems but the adjusting feature of the legs tends to solve the problem of tying the legs the proper length. Previous testing has shown that due to friction within the anchor system, true equalization does not occur, hence the shift away from calling them self-equalizing. Additionally, due to the adjustability of the extensions, if one of the anchor points fails, slack is created within the anchor system that results in dynamic loading as the load is redistributed to the remaining anchor points.



Examples of Load Sharing Anchors



Load-Distributing Anchor

Part one of these tests was designed to evaluate how well the load is spread over three- point anchor systems and whether the variability of the load-distributing anchor does a better job than a load-sharing anchor at spreading out the forces.

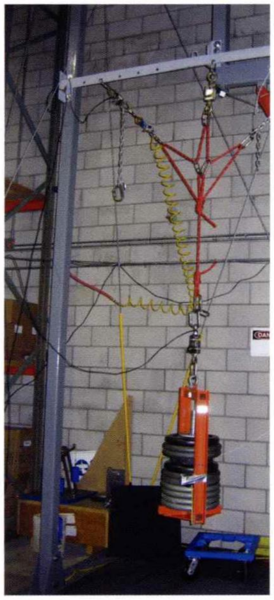
Part two was designed to evaluate the results of an anchor point failure. We wanted to see how much dynamic loading and load shift are created within each anchor system when different anchor points are deliberately failed.

The Test Set-Up

Three anchor points were rigged on a drop tower with load cells to measure the force on each. Anchor point #1 was on the left with an Omega 3000# load cell. Anchor point #2 was in the middle with an Omega 5000# load cell and Anchor point #3 was on the right with an Omega 5000# load cell. An Omega 10,000# load cell was between the anchor and the load to measure the maximum arrest force. A pneumatically controlled release was used to simulate a failure of the anchor points. The load was 2.65 kN (595 lbf).

One variable that would reduce the maximum arrest force slightly was eliminated. Knots tighten when dynamically loaded, which helps to resolve some of the dynamic energy thereby reducing the maximum arrest force. For consistency, the test mass was dropped on each rope anchor system three times and each webbing anchor system once to set the knots.

Test Procedure



After each anchor system was rigged and visually equalized, the mass was lowered on to it. The A test results indicate the force on each anchor point at that time. Then one of the anchor points was released, simulating a sudden failure, and the maximum force on the remaining anchor points and the load was recorded in the B test. The extension of the anchor system was also recorded. Another parameter that should be considered is the sideways shift when an anchor point fails. Excessive sideways movement could cause the rope to move off edge protection, resulting in rope damage or failure. When anchor point #2 (the center one) failed, there was no shift as the forces transferred to the outside anchor points. When one of the outside anchor points failed, the load shifted to center between the two remaining anchor points, in this case about 43 cm (17 in).

The leg lengths on the load-distributing anchors were measured from where the rope bends around the carabiners.

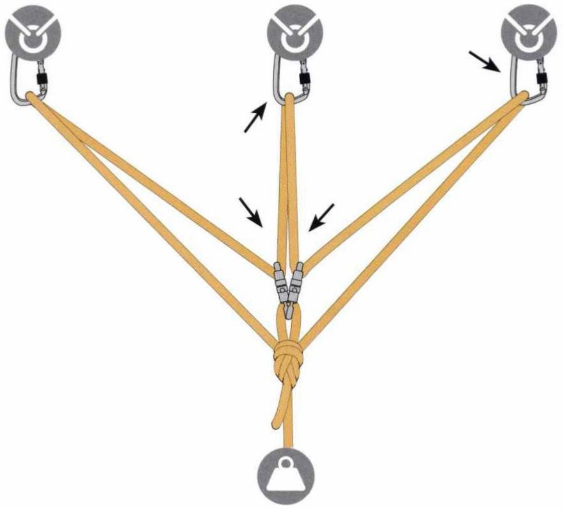
Forces for the two remaining anchor points and the load were charted for each test. The pattern for each test was similar, so only one example has been included.

CONCLUSIONS

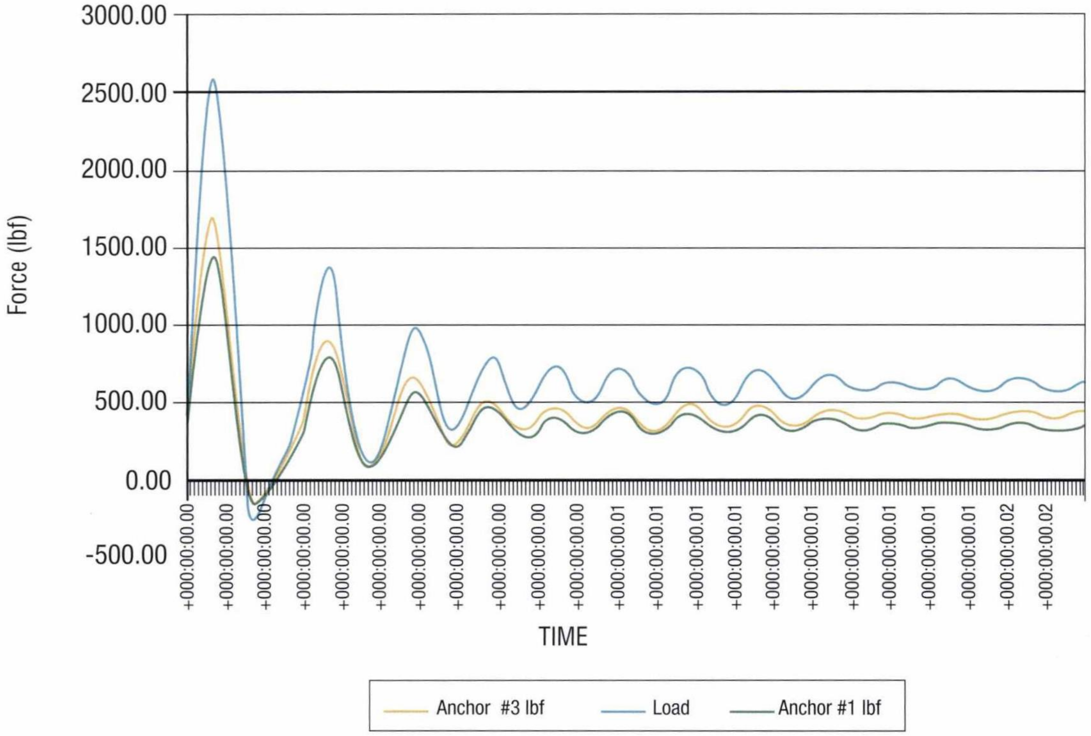
These charts are averages of the five tests we did with each anchor. None of the anchor configurations did an effective job at equally sharing the load.

When anchor point #1 failed, all the load-distributing anchors developed high maximum arrest forces (MAF) with poor equalization. The load-sharing anchor had a much lower MAF, but 87% of the load ended up on one anchor point.

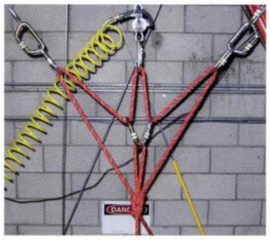
When anchor point #2 failed, some of the load-distributing anchors performed better than others with relatively small MAF and good equalization.



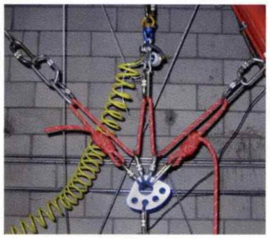
Leg Length Measurements



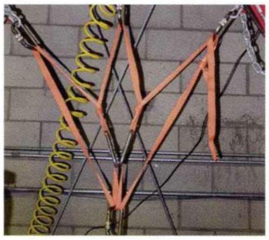
Anchor #3 = 1,721 lbf   Load = 2,592 lbf   Anchor #1 = 1,454 lbf



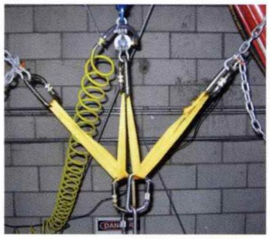
Anchor #1 – A double-loop Figure 8 knot was tied with 12.5 mm Static Pro kernmantle rope and rigged into a load-distributing anchor.



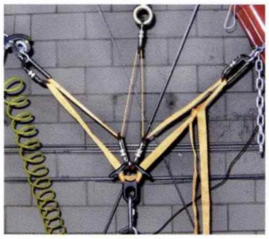
Anchor #2 – A load-distributing anchor tied with 12.5 mm static kernmantle rope, using an anchor plate as a collection point.



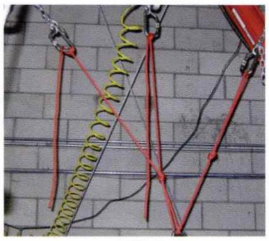
Anchor #3 – A three-way multipoint load-distributing anchor made with 1 inch nylon tubular webbing.



Anchor #4 – A sliding-X load-distributing anchor made with 1 inch nylon tubular webbing.

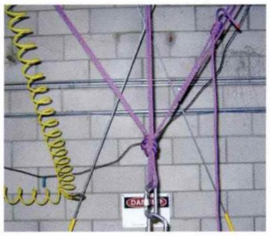


Anchor #5 – A load-distributing anchor made with 1 inch nylon tubular webbing and a Figure 8 descender as a sliding collection point.



Anchor #6 – Equalette: A load-distributing anchor made with 8 mm nylon cord. This was found in the book *Climbing Anchors*. As rigged, it is a two-point load-distributing anchor with one leg attached to a single anchor point and the second leg attached to a two-point load-sharing anchor.

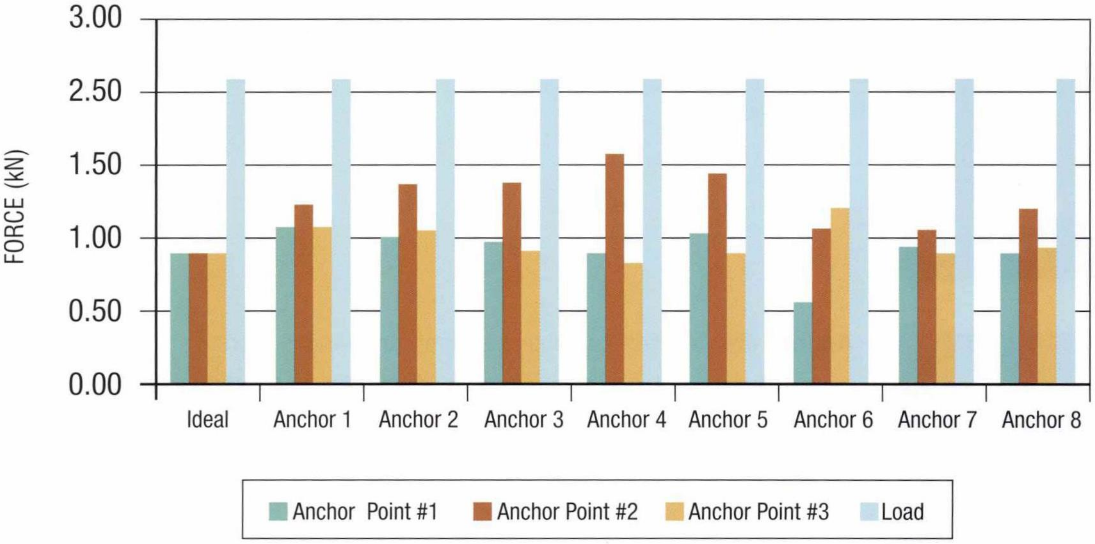
Anchor #7–A load-distributing anchor made with $^1/_2$ in nylon/Spectra webbing.



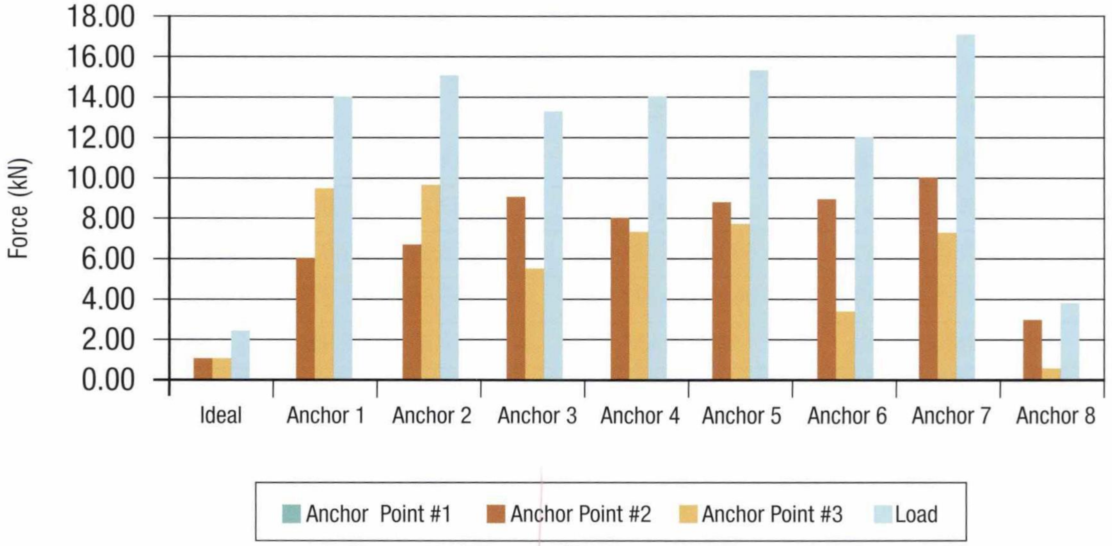
Anchor #8–A load-sharing anchor made with 8 mm cord.

CONCLUSIONS

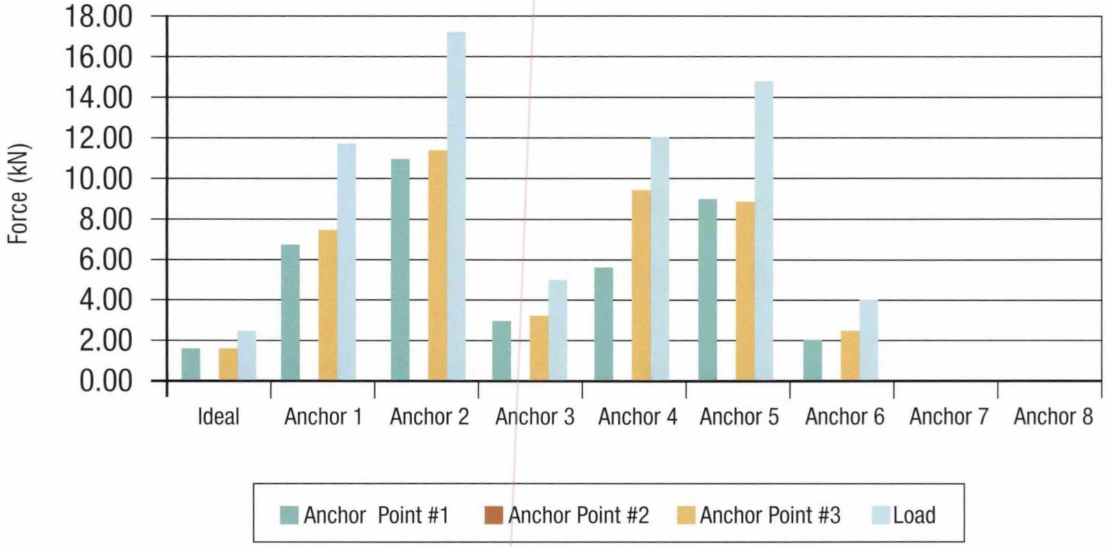
These charts are averages of the five tests we did with each anchor. None of the anchor configurations did an effective job at equally sharing the load.



TEST A



TEST B-1



TEST B-2

EFFECT OF BENDS ON ROPE STRENGTH

New 11 mm ($^{7}/_{16}$ in) rope from the same spool was used. A bight of rope was reeved around the test bollards. Both ends were secured to a standard 4 in bollard. Control samples were pulled end-to-end using the Cordage Institute slow-pull test method.

Sample	4 in Bollard (control)	0.5 in Bight	FP	1 in Bight	FP
1	28.73 kN (6.458 lbf)	44.08 kN (9,909 lbf)	A	53.13 kN (11,944 lbf)	A
2	29.35 kN (6,598 lbf)	46.65 kN (10,487 lbf)	A	53.64 kN (12,058 lbf)	A
3	29.66 kN (6,667 lbf)	47.05 kN (10,577 lbf	A	55.06 kN (12,377 lbf)	A
4	29.87 kN (6,715 lbf)	47.17 kN (10,694 lbf)	A	57.76 kN (12,984 lbf)	A
5	30.10 kN (6,766 lbf)	48.08 kN (10,808 lbf)	A	58.32 kN (13,110 lbf)	A
3σ	27.95 kN (6,283 lbf)	42.09 kN (9,461 lbf)		48.50 kN (10,903 lbf)	

Sample	1.5-in Bight	FP	2-in Bight	FP	4-in Bight	FP
1	60.25 kN (13,544 lbf)	A	60.72 kN (13,650 lbf)	B	61.84 kN (13,902 lbf)	B
2	61.05 kN (13,724 lbf)	A	60.80 kN (13,668 lbf)	A	62.71 kN (14,097 lbf)	B
3	61.06 kN (13,726 lbf)	A	61.42 kN (13,807 lbf)	A	63.11 kN (14,187 lbf)	B
4	61.47 kN (13,819 lbf)	A	63.01 kN (14,165 lbf)	A	63.13 kN (14,192 lbf)	A
5	62.39 kN (14,025 lbf)	A	63.72 kN (14,324 lbf)	A	63.60 kN (14,297 lbf	B
3σ	58.91 kN (13,243 lbf		57.86 kN (13,007 lbf)		60.69 kN (13,690 lbf)	

FP = Failure Point A = Failure at the Bight B = Failure at the Bollard

Percent Loss Due to Bend in the Rope

Bollard Diameter	3σ Breaking Point	Average Loss Due to Bending
4 in (9.1 x rope diameter)	60.69 kN (13,690 lbf)	0%
2 in (4.5 x rope diameter)	57.86 kN (13,007 lbf)	5%
$1^{1}/_{2}$ in (3.4 x rope diameter)	58.91 kN (13,243 lbf)	3%
1 in (2.3 x rope diameter)	48.50 kN (10,903 lbf)	20%
$^{1}/_{2}$ in (1.1 x rope diameter)	42.09 kN (9,461 lbf)	31%

RESULTANT FORCE (KN) FOR A GIVEN SLOPE ANGLE AND MASS

Angle (°)	Mass				
	200 kg	**300 kg**	**400 kg**	**500 kg**	**600 kg**
	440 lb	**660 lb**	**880 lb**	**1100 lb**	**1320 lb**
0°	0.00	0.00	0.00	0.00	0.00
5°	0.17	0.26	0.34	0.43	0.51
10°	0.34	0.51	0.68	0.85	1.02
15°	0.51	0.76	1.02	1.27	1.52
20°	0.67	1.01	1.34	1.68	2.01
25°	0.83	1.24	1.66	2.07	2.49
30°	0.98	1.47	1.96	2.45	2.94
35°	1.12	1.69	2.25	2.81	3.37
40°	1.26	1.89	2.52	3.15	3.78
45°	1.39	2.08	2.77	3.47	4.16
50°	1.50	2.25	3.00	3.76	4.51
55°	1.61	2.41	3.21	4.02	4.82
60°	1.70	2.55	3.40	4.25	5.10
65°	1.78	2.67	3.55	4.44	5.33
70°	1.84	2.76	3.69	4.81	5.53
75°	1.89	2.84	3.79	4.74	5.68
80°	1.93	2.90	3.86	4.83	5.79
85°	1.95	2.93	3.91	4.88	5.85
90°	1.98	2.94	3.92	4.90	5.88

Non-shaded areas represent at least a 10:1 SSSF when using a 11 mm rope with a knotted breaking strength of 21.7 kN. Lightly shaded areas represent at least a 10:1 SSSF when using a 12.5 mm rope with a knotted breaking strength of 31.7 kN. Force levels that exceed a 10:1 SSSF for both ropes are in the darkest areas.

Force Calculations by Rigging for Rescue® used by permission.

A

Abrasion—The damage caused by friction when two moving objects come in contact, such as a rope or webbing on an unprotected edge.

Access Zone—A rope access term referring to the area in which people are at risk of falling. Usually while on rope or within 6 feet of an unprotected edge.

Accessory Cord—A generic name for 3 to 9 mm kernmantle cord. Sometimes called Prusik cord, accessory cord is used for Prusik loops, tag lines and various rigging and lashing applications.

Actual Mechanical Advantage—A mechanical advantage system calculation that includes pulley efficiency.

A-frame—A high directional with two legs that join at the top. Also known as a bi-pod. It must be guyed for stabilization.

After Action Review—See Debriefing.

Aid Climbing—The technique of using gear to support the climber's weight while climbing.

Anchor—A generic term for a combination of anchor points, rope, web and hardware that creates a secure attachment point to an immovable object such as a rock, tree, structural element or vehicle.

Anchor Plate—A flat metal device with a large diameter hole for use as a collection point for anchor systems and smaller holes to separate the carabiners attaching the system's components.

Anchor Plate

Anchor Point—The object that web or rope is attached to or tied around. This could be a boulder, tree, piton, fire truck, I-beam or even a small building.

Anchor Slings—Flat or tubular webbing components that wrap around an anchor point for the purpose of attaching system components.

Anchor Strap—A manufactured component for wrapping an anchor point. Usually made of web with the ends terminating in D-rings or sewn loops.

Anchor Strap

Anchor System—A group of anchor points connected together to form an anchor. If a single anchor point should fail, the system will remain intact, allowing the other anchor points to support the load.

ANSI—American National Standards Institute. An organization that oversees the committees that develop the national standards often referenced by OSHA.

Applied Force—See Resultant Force

Aramid—A manufactured fiber in which the fiber-forming substance is a long-chain synthetic polyamide in which at least 85% of the amide linkages are attached directly to the aromatic rings. Common brand names of these flame and high temperature-resistant fibers include Nomex®, Kevlar®, Technora® and Twaron®.

Arm Rappel—A type of rappel in which the rappeller wraps the rope around their arms and across their back for friction. It cannot be used for steep terrain. Also called a Guide's Rappel.

Artificial High Directional—a man-made high anchor used to support a change-of-direction pulley. Examples include tripods, gin poles, bi pods and other similar specialized devices.

Ascending—the act of moving up a fixed rope using specialized mechanical devices or friction hitches.

Ascenders—Mechanical devices used to grip a rope to permit the user to ascend. Most designs use a cam that slides up the rope, then grips when the ascender is pulled downward. Available in handled and non-handled versions, ascenders are sometimes used in other applications where gripping the rope is required, such as haul system ratchets or to grip a rope for pulling. Knots, such as the Prusik hitch, are often referred to as soft ascenders.

Handled Ascender

ASTM International—A not-for-profit organization that provides a forum for the voluntary development of consensus standards for materials, products, systems and services. Formerly American Society for Testing and Materials.

Authority Having Jurisdiction—An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation or a procedure.

Authorized Person—A person approved or assigned by the employer to perform a specific type of duty or duties or to be at a specific location or locations on a job site.

Autoblock—A friction knot used as a self-belay on a rappel, usually positioned below the descent control device and attached to the harness.

Automatic Belay—A belay system that does not require a thinking reaction on the part of the belayer to activate the belay.

Auxiliary Equipment—Load bearing equipment designed to be utilized with life safety rope and harnesses.

Auxiliary Tender—an additional rescuer who rappels or ascends with the litter to assist with medical care or handling the litter.

Awareness Level—The most basic of the three levels of operational capability: awareness, operational and technician. Awareness level personnel and organizations are trained to recognize a technical rescue incident, know who to respond to the incident and to initiate the incident command structure.

AZORP—Arizona Omni Rigging Pod. A specialized auxiliary piece of hardware for the Arizona Vortex providing additional attachment points.

B

Back Tie—a connection from the primary anchor to a secondary back up anchor

Backing Up—Rigging a redundant system of equal strength to the primary system, which will catch the load if the primary system fails. Typically, anchors or anchor systems are backed up.

Bailout—In rope rescue, bailout is an emergency evacuation from a higher level using rappel techniques, usually referred to as escape.

Basket Hitch—A sling around an object (or an anchor point) where the two ends come together to be connected.

Basket Hitch

Basket Litter—A patient transport device that consists of a metal frame, a surface for the patient and a protective mesh attached to the frame. Often called a Stokes litter after the person who designed the original military versions. Litter is used interchangeably with stretcher.

Basket Litter

Bauman Bag—Rainy Day Equipment's patient packaging and lifting device consisting of a hammock like stretcher supported by several straps terminating at a single point for attachment to a helicopter winch or long line. See also CMC Helitack Airbag.

Becket

Becket—An attachment point on a piece of equipment, such as a pulley, that is used for connecting additional equipment.

Belay—A climbing term for a safety line. A system to provide fall protection or fall arrest for yourself or another person.

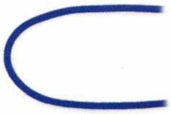
Belay—The act of tending a belay or safety line to protect another person ascending or descending.

Belay Line—A line designated to provide fall protection. In a two-line system, the main line controls the movement of the load while the belay line catches the load if a main line failure occurs.

Bend—A knot that connects the ends of two lengths of rope or web together.

BFR—A slang term used by rescuers to describe a very, very secure anchor point. Originally it referred to a very BIG rock but could refer to any immovable object, such as large trees, fire trucks, water tanks or bridge abutments. Immovable is the key element, which usually, but not always, equates to size.

Bight—Formed when the rope is doubled back but does not cross itself.



Bight

Block and Tackle—A simple mechanical advantage system with a single rope reeved through a series of pulleys.

Block Creel—A type of rope construction in which there are no knots or splices in the yarns, strands or braids of the rope.

Body Belt—A belt that fits around the waist and has a load-bearing attachment point. Some standards now limit the use of a body belt to travel restraint, positioning on a ladder or emergency escape.

Bolts—A semi permanent, artificial anchor consisting of a metal device inserted into a hole drilled in rock or concrete.

Bombproof—An adjective for an anchor or anchor point that the rescuer is absolutely certain will support the expected and any unexpected loads placed on the rope system.

Bottom Belay—A belay method in which the rappel rope is tended at the bottom by the belayer. By pulling down on the rope, the belayer can slow or stop the descent. A bottom belay protects against a loss of control by the rappeller but does not protect against a failure of the anchor or rappel line or a failure to correctly rig the descender onto the rappel line.

Brake Bar Rack—A lowering or descent control device utilizing a series of bars oriented in a ladder like pattern on a J- or U-shaped steel frame.

Brake Hand—The hand used during descents or while lowering on rope to maintain control by gripping the rope.

Bridle—Along with Spider, another name for a litter or stretcher harness.

Bridle

C

Cam—The moving element of an ascender or rope grab that is forced toward the frame or shell to grip the rope when a load is placed on the device. Sometimes used as a slang term for a rope grab used in a rope rescue mechanical advantage system.

Capstan—A mechanical device in which a rope attaches to a rotating drum by means of multiple wraps.

Carabiner—A D- or oval-shaped load-bearing connector with a self-closing gate used to join life safety rope and system components.

Capstan

Carabiner Wrap—A rappel technique that uses the friction created by several wraps of rope around a carabiner for control.

CE—The abbreviation for the European Committee for Standardization, the standards setting body for the European Union.

Chain Stitch—A type of construction of tubular web in which two layers of flat web are folded then stitched together on the edge using a lock stitch. It is manufactured on needle loom machines.

Carabiner

Change-of-Direction Pulley—A non-moving pulley that changes the direction of the rope but provides no mechanical advantage. Sometimes referred to as a directional.

Changeover—The process of changing from lowering to raising, rappelling to ascending or vice versa.

Chest Harness—A type of harness worn around the upper torso for additional support. It should be used in conjunction with a seat harness, never alone.

Chicken Loop—An ankle strap that secures the climber's foot loop to their feet and ankles

Class I Harness—An early NFPA Standard 1983 designation for a harness that fits around the waist and thighs and designed to be used for rescue and has a design load of 300 pounds. Since deleted from the standard.

Class I Lever—A simple mechanical device where the fulcrum is between the force and the load. The force applied to the lever moves the load in the opposite direction. A seesaw is a class I lever.

Class II Harness—The NFPA Standard 1983 designation for a harness that fits around the waist and thighs designed to be used for rescue and has a design load of 600 lbf.

Class II Lever—A simple mechanical device where the load is between the applied force and the fulcrum. Examples are a wheelbarrow or the moving pulley in a mechanical advantage system.

Class III Harness—The NFPA Standard 1983 designation for a harness that fits around the shoulders, waist and thighs designed to be used for rescue and has a design load of 600 lbf.

Class III Lever—A simple mechanical device where the force is applied between the load and the fulcrum. A fishing rod and a shovel are examples of class III levers.

Command Post (CP)—The location at which the primary command functions are executed. The CP may be colocated with the incident base or other incident facilities.

Competent Person—A person who by training or experience is capable of identifying existing and predictable hazards in the surroundings or working conditions that are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective action to eliminate them.

Complex System—A rope rescue mechanical advantage system that is neither a simple system nor a compound system.

Component Testing—A measurement of how a single piece of equipment performs against a standard.

Component—A single piece of equipment in a system.

Compound System—A rope rescue mechanical advantage system in which a simple system is pulling on another simple system.

Conditional Belay—A belay that is only valid if certain conditions are met. For example, a self—belay using a Prusik hitch on a rappel line is only valid if the rappeller releases the Prusik hitch and the rope is not compromised.

Confined Space—A space that a person can enter and do work but has limited means of ingress or egress and is not intended for continuous human occupancy. 29 CFR 1910.146

Contingent Anchor—A lowering (or raising) system incorporated into the anchor to allow a person stuck on line to be quickly rescued by lowering (or raising) the line.

Control Line—The lines that move the load across a high line. They also serve as the belay in case of a track-line failure; tag line.

Cordage—Rope, webbing or accessory cord

Counter Balance—A rope rescue system that uses a change-of-direction pulley and an offsetting load. The offsetting load traveling down reduces the force that the haul team needs to exert to lift the primary load.

Critical Incident Stress Debriefing—Also Critical Incident Stress Management. A preplanned process for identifying and treating psychological trauma resulting from participation in an incident.

Critical Point Analysis—A look at each component of the rope rescue system and asking whether a failure of that component would cause a catastrophic failure of the entire system.

Critique—An honest, searching evaluation of the performance of the rescue team for the purpose of improving the service provided to the community. The inability to critique suggests a dangerous overconfidence based on intentional ignorance.

D

D-Ring—A metal load-bearing connector shaped like the letter D and used as an attachment point on various components, such as harnesses and anchor straps.

D–Ring

Debriefing—A session following an incident to critically analyze all conditions and actions taken in the management of that emergency. The purpose is to determine effectiveness of operations and how to improve them when managing similar incidents in the future.

Deflection Line—A rope system used to position a pulley to deflect a loaded line away from an obstacle.

Descender—A device that provides friction to control the rate of descent on a rope.

Descent Control Device (DCD)—A friction device attached to a rope to control the lowering of a load, used as a descender for rappels or as a brake for lowering systems.

Destructive Test—A test method in which the test sample is taken to failure.

Deviation—A change or redirection of the path of a rope usually by using a carabiner connected to a sling and anchor. The deviation should not redirect the rope more than 30 degrees.

Directional—Using a pulley to bend a line to turn corners in the ascent or descent or to place the haul or belay system into a more efficient direction of travel; change-of-direction pulley.

Dogging the Tails—Also known as Dog-N-Tails or French Braid, it is a rope grab knot formed by doubling over a small cord, connecting it to an anchor and braiding the two ends multiple times over the main line in opposite directions. It is easily released after loading.

Double Double—A slang term for a 4:1 mechanical advantage using two double sheaved pulleys. Also the most commonly ordered menu item at In and Out.

Double Line Lowering—A technique in which two ropes are attached to the litter, one at each end, and each is controlled by its own friction device.

Double Pulley—A pulley with two sheaves.

Dressing—Eliminating open loops and twisted or crossed rope segments to allow a knot to tighten in a neat, orderly fashion for the purpose of maximizing knot strength.

Drop Line—A lightweight cord (8 to 9 mm) used to pull additional equipment to a roof or other high location.

Dulfersitz—German for hot seat. A rappel method that does not use a harness or descent control device. The rope is wrapped through the legs and over the shoulder. Also known as a body rappel.

Dynamic Load—A force rapidly applied to a system, such as when a fall is arrested by a safety or belay line, sometimes referred to as an impact force or impact load.

Dynamic Rope—A rope designed to minimize the impact force of a fall through elongation, such as a recreational climbing rope. Low-stretch ropes are defined as less than 10% elongation at 10% of breaking strength, suggesting that a dynamic rope would be a rope with greater than 10% elongation.

Dynamometer—An instrument used to measure tension on a line. A force gauge.

E

Edge Roller—A type of edge protection consisting of one or more moving rollers to reduce friction and protect the rope moving over a sharp edge.

Edge Tender—The rescue team member responsible for assisting with getting the litter over the edge.

Edge Transition—The process of maneuvering a rescuer or litter over an edge. The change between horizontal and vertical movement.

Edgeman—Also called an edge tender, it is a person positioned at the edge of a vertical space who can assist with moving the litter over the edge, relaying communications as needed and tending edge-protection devices. In a high angle rescue, the edgeman is capable of descending and ascending. Otherwise, if a fall hazard exists, the edgeman is provided with a travel restraint line.

Electronic Load Cell—A dynamometer or force gauge using electronics rather than mechanical components to measure a load.

Elevated Rescue—A rescue of a subject from a height where normal means of egress are not available.

Elongation—The amount that a rope stretches at a specified load, usually reported as a percentage of the rope's length before the load is applied.

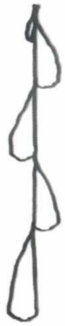
Emergency Seat Harness—A temporary harness tied from rope or webbing used when a manufactured seat harness is not available.

English Reeve—A type of rigging where the load can be raised or lowered from either end of the highline.

Escape—In rope rescue, escape is emergency evacuation from a higher level using rappel techniques, sometimes referred to as bailout.

Escape—An equipment designation in NFPA 1983 Standard on Life Safety Rope and Equipment for Emergency Services. Escape has the lowest performance requirements of the three designations: general, technical and escape.

Etrier—A set of loops or stirrups sewn or tied from webbing and used for ascending. It is a French climbing term pronounced á-tray-á.



Etrier

Exposure—The status of being near or in the vicinity of a physical hazard. In rope rescue this is usually near an edge with a fall hazard but also includes mechanical, temperature, biological or radiological hazards.

F

Fall Arrest—Stopping the downward movement of a falling individual.

Fall Factor—The height of a fall divided by the length of the rope available to arrest the fall. Essentially the fall factor value compares the potential energy in the system with its capacity to absorb that energy. The higher the fall factor, up to a maximum of two, the greater the severity of the fall.

Fall Protection—Equipment or procedures that prevent a person at height from falling or should a fall occur, arrests the fall. Fall protection can be part of the structure, worn by the person or procedural policy. It includes both fall arrest and travel restraint.

Festoons

Festoons—Connectors constructed of short loops of cord or webbing that slide along the track line to support the control and reeving lines in a high-line system.

Fid—A long, sometimes tapered, tube used for splicing double braid ropes. Traditionally a long tapered wooden tool, similar to a marlinspike without the protruding head.

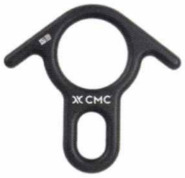


Figure 8 Descender

Field Test—Verification of performance under typical conditions of use.

Figure 8 Descender—A metal plate with the approximate shape of the Arabic numeral 8, used as a descent control device.

Fixed Brake—A friction device is attached to an anchor at the top of a lower in which the rope moves through.

Fixed Line—A non-moving rope attached to an anchor. Rappels are on a fixed line but the term most often refers to a rope used for ascending, for a safety line or as a hand line when climbing or descending a slope.

Fixed Pulley—See Change-of-Direction Pulley.

Fixed Rope—See Fixed Line.

Flaking—To lay the rope out for the most efficient deployment and to prevent kinks and tangles.

Flexible Litter—A litter without a rigid structure that can be closely wrapped around the patient.

Flying "W"-A slang term that refers to the shape of the 6:1 dual highline tensioning system.

Force Multiplier—A rigging effect that causes the force on a component of the system to be greater than the load. An example is a rope running through a change-of-direction pulley where the rope turns 180° (0° interior angle). This increases the force on the pulley by two times the force of the load.

Full-Body Harness

Friction—The rubbing of one object or surface against another that resists the motion of one relative to the other. Friction increases the work that a haul team must do to lift a load but reduces the load on the system during lowering.

Full-Body Harness—A harness that fastens about the upper thighs, pelvis, torso and shoulders. A NFPA 1983 Class III harness is a full body harness.

G

Gain—A term used to describe the size of the loop in a knot.

General Use—An equipment designation in NFPA 1983 Standard on Life Safety Rope and Equipment for Emergency Services. General use has the highest performance requirements of the three designations: general, technical and escape.

Gin Pole—A high directional consisting of a single leg. It must be guyed for stabilization. Also called a monopod.

Gram (g)—The SI unit of measure for mass equivalent to 0.0353 ounces.

Guide Hand—The hand that is used to help balance a person on rappel. It is usually their non-dominant hand.

Guiding Line—A system that combines a tensioned line and a lowering system, allowing a litter to be kept away from the surface during a lowering.

Guy Line—A rope that angles from the top of a monopod or bi-pod to the ground to stabilize it.

H

Hand line—A fixed line used to assist and to self-belay an ascent or descent by providing a rope to hold onto. The rope is usually gripped by the hand but a rope grab could also be used.

Hardware—Any metal components used in a rescue system

Harness—A arrangement of materials secured about the body to support a person.

Harnesses Suspension Pathology—A condition that occurs when a person hangs motionless in a harness for a period of time. There are several variables involved but this can result in unconsciousness and death in a relatively short time. Also called suspension intolerance, harness induced pathology or harness hang syndrome.

Haul Cam—The rope grab used to attach a moving pulley to the rope when assembling a mechanical advantage system. This is different from the ratchet cam, which connects to the anchor and holds the load while the system is being reset or modified.

Haul Field—The area available to a team to move while operating a raising system.

Haul Line—The rope carrying the load in a traditional loaded main/slack belay raising system

Haul Team—The individuals doing the work to raise the load.

Hazard Reduction—The elimination or mitigation of a hazard within a specific area, such as a travel restraint system or belay line for a rescuer working near the edge.

Hazard Zone—Any area where the rescuers, workers or public are at risk of injury from the work being performed. (e.g. falling rocks, tools, etc.)

Helmet—A protective head covering usually made from rigid plastic with a suspension and attachment devices.

High Anchor Point—An attachment point for a rope rescue system component elevated above the working level of the system.

High Angle—When the angle of the terrain becomes so steep that the weight of the individual or the litter is supported primarily by the rope rather than by the feet.

High Line—A system consisting of one or more ropes or cables suspended between two points for movement of persons or equipment over an area that would otherwise be a barrier to rescue operations.

Hitch—A knot that attaches a rope to another object, including another rope if the host rope is not part of the knot. In most cases a hitch can be slid along the object and will fall apart if the object is removed.

HMS—A pear shaped carabiner used for a Munter or Italian hitch belay. The name is an abbreviation of the German term ***Halbmastwurfsicherung,*** which means half of a clove hitch belay.

Hobbling—The act of securing the legs of a tripod or bi-pod together to prevent their outward movement or splaying, when loaded

Horizontal Litter—When the litter is positioned perpendicular to the rope (or the fall line).

Horizontal Rescue—Rescue procedures where the individual's weight is supported by a horizontal surface, such as a floor or horizontal surface inside the space.

Hot Zone—The area where it is considered dangerous and specialized protective gear must be worn. This might be fall protection at the top or below, protection from objects falling.

Hypothermia—A decrease in body core temperature.

I

Impact Load—See Dynamic Load.

Incident Action Plan—The plan developed at the field response level that contains objectives reflecting the overall incident strategy and specific tactical actions and supporting information for the next operational period.

Incident Command System (ICS)—The nationally used standardized on-scene emergency management concept specifically designed to allow its users to adopt an integrated organizational structure equal to the complexity and demands of single or multiple incidents without being hindered by jurisdictional boundaries. ICS is the combination of facilities, equipment, personnel, procedures, and communications operating within a common organizational structure, with responsibility for the management of resources to effectively accomplish stated objectives pertinent to an incident.

Incident Commander—The individual responsible for the command of all functions at the field response level.

Independent Belay—A belay system that is entirely separate from the main line system. It provides the highest level of protection but requires a second anchor, rope, hardware and operator.

Independent Self-Belay—A belay that protects against the failure of the rappel system but does not have a separate person managing the belay, for example, a safety line with a fall-arresting device.

Inherently Tight / Inherently Loose—Describes the ability of a knot to stay tied or to untie during normal use. Inherently loose knots require the use of a backup or safety knot to make them hold their shape.

Inline Litter—The rope connects to the head of the litter letting the litter hang in line with the rope.

IRATA—International Rope Access Trade Association. A group based in Great Britain

ITRA—International Technical Rescue Association. An organization with international membership formed to establish training and certification standards for various rescue disciplines.

ITRS— International Technical Rescue Symposium—An annual meeting of influencers from various technical rescue disciplines to present research on new equipment and techniques and to tell war stories.

J-Rack (shown without bars)

J

J-Rack—A type of Brake Bar Rack that has a J-shaped frame.

K

Kernmantle—German for core (kern) and sheath (mantle), refers to a type of rope construction in which a load-bearing core is covered by a protective sheath.

Kernmantle

Kevlar®—A brand of aramid fibers manufactured by DuPont and used to manufacture rope, cord, web and fabrics. Kevlar fibers have a high strength-to-weight ratio, very low elongation and a high heat and flame resistance.

Kilogram (kg)—One thousand grams, the SI unit of mass most commonly used by rope rescue practitioners, equivalent to 2.2 lb.

Kilonewton (kN)—One thousand newtons, the SI unit of force most commonly used by rope rescue practitioners, equivalent to 224 lbf.

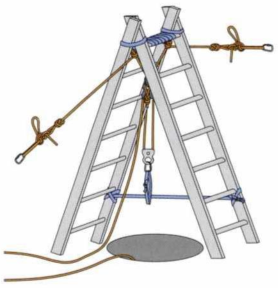
Knot—A fastening made by tying rope or cord. Knot is generic but also specifically applies to any knot that is not a hitch or a bend.

Kootenay Carriage—A specialized pulley with a wide sheave and multiple attachment points that allows it to pass knots in rope or to accommodate up to four ropes.

Ladder Belt— A belt that is intended for use as a positioning device for a person working on a ladder.

L

Ladder Rig—A 2:1 M/A on a high directional anchor constructed using ground ladders.



Ladder Rig

Laid Rope—A type of rope construction in which three or more strands are twisted together.

Laid Rope

Lanyard—A section of rope or webbing used to connect a harness to a rope or anchor.

Lashing—The process of using rope to connect two or more items together in a somewhat rigid manner. In rescue applications we lash spars together to form tripod or bi-pod high directional.

Latch—A fastening device that consists of a bar that falls into a notch to prevent opening or operation of the object it secures.

Lead Climbing—A method of protecting the first person who is climbing or traversing when the rope or safety system does not exist. The belay rope is attached to the climbing surface at regular intervals as the climber progresses.

Ledger Pole—A third pole lashed across the base of an A-frame to make it a triangle, added for increased stability.

Liaison Officer—A member of the command staff at the field level responsible for coordinating with representatives from cooperating and assisting agencies. At emergency operations center (EOC) levels, the function may be done by a coordinator and/or within a section or branch reporting directly to the EOC director.

Life Safety System—The combination of all of the components that directly support a life during a rescue operation.

Light Use—An equipment designation in NFPA 1983 Standard on Life Safety Rope and Equipment for Emergency Services, which has been changed to technical use. This has the middle performance requirements of the three designations: general, technical and escape.

Line—Another term for a rope, usually refers to a rope that is in use.

Litter—A transfer device designed to support and protect a patient during movement. Also called a stretcher, the terms are used interchangeably.

Line Transfer—A rope rescue skill for transferring an individual on a line to a rescue line or system.

Litter Attendant—Person or persons assigned to manage the litter during movement. Litter tender is becoming the preferred term since the attendant is a unique position in confined space rescue. The litter tender guides the litter around obstacles, tends to the patient and communicates with the rescuers operating the rope systems.

Litter Bridle—See Bridle.

Load—A generic term for the force generated by everything that is hanging on the rope at the end away from the anchor. This could include a rescuer, patient, litter and tender(s), everyone's gear and the system hardware. The load lifted by the haul team also includes the friction in the system.

Load-Distributing Anchor System—An anchor system that, in theory, automatically equalizes the load among two or more anchor points as the direction of pull shifts or if any anchor points should fail. Friction in the system prevents the loads on each anchor point from reaching an equal state and often a physical adjustment is required to create even a rough equality.

Load Limiter—A device designed to slip or release at a predetermined force to prevent excessive strain on a system. One of the advantages of using a Prusik hitch for a rope grab is that it can also act as a load limiter, slipping before the load causes a system failure.

Load Ratio—The ratio of a components minimum breaking strength to the anticipated load.

Load-Releasing Hitch—A hitch that can be untied or released while under load and then used to transfer the load to another line in a controlled manner, also called a load-release knot or mariner's knot, it can be tied from cord or web. A load-release strap is a commercially sewn version.

Load-Sharing Anchor System—An anchor system that is constructed such that the load on each leg will be as equal as possible. The actual level of equality is very dependent on the ability of the rigger to estimate the direction of pull and the length of each leg. Since the legs are of fixed length, a failure of an anchor point will cause a shift in the direction of pull but will not generate the slack in the system that a load-distributing anchor system will.

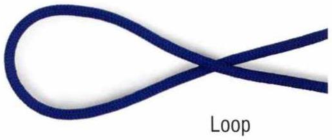
Load Release Strap

Locking Carabiner— A carabiner with a gate designed in such a way that it cannot be accidentally opened.

Lock Off—Securing the rope around a descent control device so that the rope will not slide through when the operator lets go of the rope and the device.

Loop—Formed when a rope is doubled back and crosses over itself.

Low Angle—The angle of terrain where the weight of the litter is supported primarily by the tender's legs and the rope system is required to both facilitate movement and for fall protection. The actual angle in degrees will vary depending on the type of surface and the skill level of the tenders.



Loop

Lowering—The technique used to move a load from a high position to a lower position.

Low Point Anchor—An attachment point for a rope rescue system component located at or below the working level of the system.

Low-Stretch Rope—Defined by the Cordage Institute as a rope having between 6% and 10% elongation at 10% of the rope's breaking strength.

M

Main Line—The rope designated as the primary line in a two-rope system even though both ropes may have identical set-ups or be equally loaded. In a raising system it will be the haul line with the mechanical advantage. In a lowering, it controls the rate of descent.

Major Axis—The long axis of a carabiner in which it is intended to be loaded. It is parallel to the spine of a carabiner.

Manner of Function Tests—The process of testing a piece of equipment in the manner in which it is actually going to be used.

Manual Belay—An action from the belayer is required for the belay to operate. If the belayer does not respond or makes the wrong response, the belay will not work (see Automatic Belay).

Manufactured System—A preassembled system sold as a unit by the manufacturer and tested as a complete assembly

Margin of Safety—The strength of the system divided by the maximum load that will be put on the system. The system's strength is determined by the weakest component in the system. The maximum load includes friction, force multipliers and other external forces. The margin of safety is the buffer against disaster when the rescue does not go as planned.

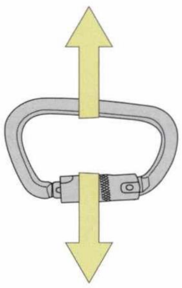
Marlinspike—A long cone-shaped tool used for spreading the strands of laid rope for splicing or when untying knots. It has a bulbous head for pounding into knots to loosen them. Traditionally made of metal. A fid is a similar tool usually made from wood.

Master Attachment Point—The point where the rigging comes together for maximum strength.

Mechanical Advantage (M/A)—Any means of increasing a rescuer's ability to lift or move a load. In rope rescue mechanical advantage almost always refers to a system using pulleys to increase the effectiveness of the haul team. M/A is referred to as the ratio between the output and the input of the system, for example a 3:1 M/A system.

Messenger Line—A small diameter (3 to 7 mm) cord sent across a span and then used to pull heavier lines across. The light weight of the messenger line allows it to be thrown or shot further than the heavier rescue rope.

Minor Axis—The short axis of a carabiner from the gate across to the spine.



Minor Axis

MRA—The Mountain Rescue Association is an organization of member teams. To join, a team is tested in three areas: high angle rock rescue, snow and ice rescue and search for lost persons.

Monopod—A high directional with a single leg. Also known as a gin pole. Monopods must be guyed for stability.

Moving Pulley—A moving pulley acts to increase the mechanical advantage in a system, mechanical advantage pulley.

Multipoint Anchor—An anchor system that uses more than one anchor point, used when an adequately strong single anchor point is not available.

Munter Hitch—A friction hitch tied around a carabiner to control a descent, such as for a belay or a rappel. Also known as an Italian hitch.

Murphy—A known associate of CMC's instructors with a propensity for showing up uninvited at your rescue. Murphy has been suspected of stealing unattached equipment, moving edge protection, tangling ropes and causing short-term memory loss.

N

Needle Loom—A type of construction of tubular web in which two layers of web are stitched together on the edge using a lock stitch.

Newton—The SI unit of force equal to approximately 0.225 pound-force (lbf).

NFPA—The National Fire Protection Association is an international non-profit organization recognized as an authority on fire, electrical and building safety. The NFPA is best known for its development of industry consensus standards and codes.

Nomex®—A brand of aramid fiber manufactured by DuPont that has an extraordinary combination of high-performance heat- and flame-resistant properties as well as superior textile characteristics.

Non-Directional—An anchor system or backed-up anchor where the load on the anchor point(s) remains roughly the same as the direction of pull shifts to one side or the other.

Non-locking carabiner—A carabiner without the means to secure the gate in a closed position

Norwegian Reeve—A highline rigging system where the load is raised or lowered from a single side.

Nylon—A polyamide fiber used to manufacture rope and webbing.

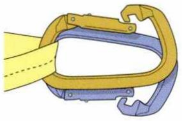
O

OATH—An acronym for remembering nonverbal communication codes, such as rapping and tapping, light flashes or rope tugs. For example:

O – OK	1 tap indicates all is okay
A – Advance	2 taps tells the other person to advance the retrieval line
T – Take up	3 taps tells the other person to take up the retrieval line
H – Help	4 taps tells the other person that help is needed or to evacuate

Operations Level—The second of the three levels of operational capability: awareness, operational and technician. Operational level personnel and organizations are trained to perform hazard identification, use equipment and perform limited technical rescue techniques, usually under the direction and control of technician level responders.

Opposite and Opposed—Positioning a pair of non-locking carabiners so that the gates will not be side by side and thus cannot both be opened at the same time.


Opposite and Opposed Positioning

OSHA—Occupational Safety and Health Administration, part of the U.S. Department of Labor responsible for developing and enforcing workplace safety and health regulations.

P

Packaging—Preparing a nonambulatory patient for transport in a litter with considerations for the medical complaints, protection from the environment and prevention of injury during the evacuation.

Performance Evaluation—Determination of whether an individual or organization can perform a standardized skill.

Picket—A metal or wood spike or stake driven into the earth or snow to form an anchor. They can be used singularly or with several connected together depending upon the strength that is required.

Pick-Off—A rescue technique in which the rescuer descends to the subject, attaches the subject to the rescuer's system and then both continue the descent to safety. Pick-offs can be done using a lowering system or on rappel. While usually performed as a descent, the rescuer and subject could also be raised. Sometimes referred to as a line transfer rescue if the subject is suspended by a rope.

Piggyback System—Sometimes called a pig rig, it is an independent rope system that attaches to the main line. Historically the term was also used for a specific 4:1 M/A system in which a 2:1 system is piggybacked on to a second 2:1 system, which is attached to the main line.

Pilot Cord—A small (1 to 2 mm) cord sent across a span and then used to pull a heavier messenger line across.

PIO—The Public Information Officer is the individual at field or EOC level that has been delegated the authority to prepare public information releases and to interact with the media. Duties will vary depending upon the agency and ICS level.

Polyester—A type of fiber used in the manufacture of rope and webbing.

Portable Anchor—A manufactured device designed to support human loads, such as davits, A-frames, tripods, quadpods and cantilevered devices.

Pound-Force (lbf)—A unit of measurement of the force on a mass by gravity; weight.

Pounds (lb)—A unit of measure for mass.

PPE—Abbreviation for Personal Protective Equipment. Equipment that is designed to protect the wearer from hazards in the work environment. Examples include: helmet, harness, gloves, respirator, and safety glasses.

Pretensioned Back Tie—Connecting a less than satisfactory anchor located at the focal point to a stronger anchor using a mechanical advantage system to tension the rope or web connecting the two points.

Precision—The least variation from a standard.

Preplan—A written plan for a rescue response that provides the organization of and initial actions for the most common incidents of the agency. It is based on past responses, hazard assessment and available resources.

Pretensioned Front Tie—Using a front anchor point to remove slack from an extended anchor system.

Primary Anchor—The anchor point within an anchor system intended to support most of the load or potential load.

Progress Capture Device—See Ratchet.

Prusik Hitch—A friction knot that can be moved along the rope but when loaded in either direction, will grab the rope.

Prusik Loop—A continuous loop of cordage used to tie a Prusik hitch

Prusik-Minding Pulley (PMP)—A pulley in which the bottom of the side plates are shaped to prevent a Prusik hitch from being pulled into the pulley and jamming.

Pulley—A simple machine consisting of a grooved wheel that rotates on a bearing and is used for altering the direction of a moving rope or for travelling on a fixed rope.

Prusik-Minding Pulley

Pulley Efficiency—The difference between the input and output forces on a pulley as a result of friction caused by the axle sheave interface or the bending and unbending of the rope as it moves through the pulley.

Q

Qualified Person—A person who, by possession of a recognized degree, certificate or professional standing, or who by extensive knowledge, training or experience has successfully demonstrated the ability to solve or resolve problems relating to the subject matter, the work, or the project.

R

RAD—An abbreviation for Rapid Ascent and Descent.

Rappel—The controlled descent on a fixed line, best done with the use of a descent control device.

Ratchet—A rope-grabbing device that attaches to the anchor and holds the rope, so that the load will not lower when the pulling force is released, sometimes referred to as a progress capture device (PCD).

Recommended Working Load (RWL)—A cordage industry term indicating the safe load for a rope. For twisted rope, it is derived by taking 8% to 11% of the new rope tensile strength for nylon and 10% to 14% for other fibers. For a braided rope it is 15% to 20% of the new rope's tensile strength. The percentage will vary by rope size and type.

Reeve—Additional rigging to a highline system to allow for lowering or raising a load from the highline carriage independently of the trackline. It is also a verb: the act of passing a rope through pulleys or other rigging equipment.

Release Knot—A type of knot that can be untied while under load. Some release knots will allow a controllable release of the load for transfer to another line.

Rescue—The location, access, stabilization and transport to safety or to medical care of a subject at risk.

Rescue Group Supervisor—The individual responsible for the rescue group, which usually includes the rigging team, medical team and litter team, reports to the operations section chief.

Rescue Load—ASTM Standard F2266-03 *Standard Specification for Masses Used in Testing Rescue Systems and Components* specifies a Type IV mass as 200 kg (440 lb) and a Type V mass as 280 kg (617 lb). The explanatory text describes the Type IV mass as representing a "rescue load with two rescuers" and the Type V mass as a "three-person rescue load."

Resultant Force—The direction of the load on the pulley and the anchor that occurs when a pulley is used for a change-of-direction.

Rigger—The individual responsible for the coordination and evacuation of the patient and entry teams and the operation of the rope rescue or retrieval systems, supervisor of the rigging team.

Rigging—The rope and hardware used to assemble a rope rescue system, including anchor systems, main line and belay line. The act of assembling a rope rescue system.

Rigging Plate—See Anchor Plate.

Rollout—A situation where a carabiner rotates and when the gate pushes against the attachment, the gate opens and the carabiner disconnects.

Rope Access—Techniques by which access gained to structures or geologic features where ropes are used as the primary means of support, positioning or safety protection.

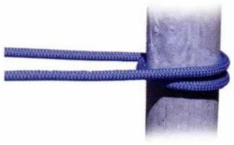
Rope Grab Device—A device used to grasp a life safety rope for the purpose of supporting a load, includes ratchets and ascenders. A rope grab can be soft, such as Prusik hitch, or hard, such as a mechanical ascender.

Rope Log—A document that tracks the history of a particular piece of rope,

Round Turn—A full wrap of rope completely around an object with both ends pointing the same direction; a 540° wrap.

Runner—A webbing loop sometimes referred to as a sling.

Running End—The end of the rope that you are working with, also called the working end, bitter end or tag end.



Round Turn

S

Safe Working Load—The maximum load which an item of equipment may safely raise, lower or suspend under particular service conditions.

Safe Zone—A rope access term for any area outside of the Hazard Zone or Access Zone

Safety Factor—See Margin of Safety.

Safety Knot—Double Overhand for rope and an Overhand Knot for web tied just behind the primary knot as a backup to prevent the primary knot from working loose.

Safety Margin—See Margin of Safety.

Safety Officer—A member of the command staff at the incident or within an EOC responsible for monitoring and assessing safety hazards or unsafe situations and for developing measures for ensuring personnel safety.

SCBA—Self-contained breathing apparatus consisting of a full face mask, respirator and air bottle**.**

Scree—Small-sized rocks usually found on slopes. In mountain rescue, a low angle evacuation is often referred to as a scree evacuation since that was the technique used for scree slopes as well as for other terrain that was close to the same angle.

Screw Link—A metal connector that uses a nut for the gate and closes by screwing the nut onto the threads on the far side of the gate.

Seat Harness—An adjustable configuration of webbing that wraps and supports the pelvic region. Also called a sit harness.

Self-Belay—A belay system operated by the person on rope. It protects against a mistake in rappelling or ascending. If it is attached to a separate safety line, it also protects against a failure in the main line and its anchor.

Self-Equalizing Anchor System—An anchor system that distributes the load to several anchor points in roughly equal amounts. The operative word is *self*, meaning that the distribution occurs without the need to re-rig the system. Due to friction in the system, the anchor system may need some assistance in equalizing the load. Also called a load-distributing anchor system.

Screw Link

Self-Rescue—The ability of the subject or entrant to exit the space without assistance.

Shall—Used in codes and standards when the provisions are mandatory.

Shared Tension System—Used in earlier editions but now more commonly known as a Twin-Tension or Two-Tension systems. See Twin-Tension System.

Sheave—The wheel in a pulley. The diameter of the sheave is measured at the tread (center) of the wheel.

Should— Used in codes and standards when the provisions are advisory.

Shuttle Loom—A construction type of tubular webbing, also called spiral stitch.

Side Load—A condition in which the force applied to a carabiner improperly comes from the side, essentially attempting to bend the carabiner.

Side Plate—The large, flat part of a pulley that attaches to the axle and wheel assembly and has a hole or other attachment at the top for the carabiner. On many rescue-type pulleys, the side plates rotate to allow the pulley to be attached without having to thread the end of the rope through.

Simple Anchor—An anchor with a single anchor point. A high-strength tie-off around a strong tree is an example of a simple anchor.

Simple System—A rope rescue mechanical advantage system in which all the moving pulleys travel in the same direction and at the same speed as the load.

Single Line Lowering—The use of a single load bearing line (with a safety belay) to lower a load.

Single-Rope Technique (SRT)—The use of a single rope (without a safety belay) for ascending, descending or rescue.

Size-Up—The rescue team leader's on-scene analysis of the parameters of the incident, including type of rescue involved, number of subjects, resources responding, physical and environmental hazards and the need for any additional resources, special capabilities or logistics.

Skate Block—A pulley that is attached to the load through which the primary line travels.

Skate Block System—A rigging technique using a skate block attached to the load which allows it to be kept a short distance from a vertical surface.

Snap Link—A term common in the military for a carabiner.

Soft Ascender—An ascender constructed of knotted cordage.

Software-Non—metal rigging equipment such as rope and webbing.

Spider—See Bridle.

Spiral Stitch—The type of construction of tubular web produced by a shuttle loom. The fibers appear to spiral around the webbing.

SPRAT—The Society of Professional Rope Access Technicians is an organization of individuals and companies in the rope access industry. Through a consensus process SPRAT develops safe practice standards and Rope Access Technician certification standards.

Standard Deviation—A statistical measure of the amount of variation or dispersion of a set of values.

Standing End—The part of the rope that is attached to something, usually an anchor; the inactive part as opposed to the working part.

Static Rope—Defined by the Cordage Institute as a rope having less than 6% elongation at 10% of the breaking strength.

Stationary Brake—The descender or brake device attached to the anchor.

Stokes Basket—See Basket Litter.

Stopper Knot—A knot, usually a Figure 8 or overhand, tied in the end of a rope to prevent equipment from sliding off the end of the rope or to warn a person on rappel that the end of the rope has been reached.

Stretcher—See Litter; the terms are used interchangeably.

Support (Cold) Zone—The area outside of the exclusion (hot) zone in which PPE or other safety equipment is not required. In rope rescue this is usually away from the edge of the building or cliff.

Swivel—A device that allows free rotation of attached parts to eliminate twisting.

System—A combination of all of the components required to become a functioning unit.

System Safety Factor—The ratio between the maximum load anticipated on a system and its breaking strength. The higher the ratio the greater the safety factor.

T

T-Method—A system for calculating the input/output ratio of a mechanical advantage system.

Tag Line—A line tied to entrants or rescuers in a space and dragged behind them to aid in locating them in the event of an emergency; a line attached to the litter to prevent it from spinning on a vertical lift or to pull it away from obstacles.

Tail—The end of the rope coming out of a knot. The rope exiting the friction device and behind the operator of the device.

Tailer—The person who manages the ends of the ropes that are not carrying the load (tails) in lowering systems.

Tandem Prusik Belay—Two three-wrap Prusik hitches spaced slightly apart on the belay line and connected to the belay anchor through a load-releasing hitch or device.

Technical Use— Formerly Light Use, an equipment designation in NFPA 1983 Standard on Life Safety Rope and Equipment for Emergency Services. Technical use has the middle performance requirements of the three designations: general, technical and escape.

Technician Level—The highest of the three levels of operational capability: awareness, operational and technician. Technician level personnel and organizations are trained to perform hazard identification, use equipment, perform advanced technical rescue techniques, supervise other responders and manage technical search and rescue incidents.

Technora—A brand name for a Aramid fiber manufactured by Teijin.

Telpher—See High Line.

Tether Line—A safety connection between two points. Usually to prevent an artificial high directional from toppling over the edge when being placed in position.

Theoretical Mechanical Advantage—The mechanical advantage of a system calculated without including friction or pulley efficiency.

Throw—The distance the mechanical advantage pulleys travel in a hauling system.

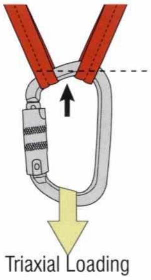
Travel Restraint—A rope or system that prevents a rescuer from getting too close to an edge.

Traveling Brake—The descender or brake device attached to the moving load, such as the litter or person rappelling.

Traveling Pulley—See Moving Pulley.

Tread—The bottom of the curve of the sheave of a pulley. This is the proper measure of pulley size as it gives the true indication of the bend in the rope.

Triaxial Loading—Where the force on a carabiner is exerted in three directions rather than along the main axis. This shifts the load away from the spine of a carabiner with a reduction in its functional strength.



Triaxial Loading

Tripod—A portable anchor device with three legs used as a high point anchor for access or retrieval or as a high directional.

Tumble—When a knot comes untied as the result of repeated loading.

Twin-Tension System—A rope system where each line acts as both a main and belay line, each sharing as close to equal tension as the operators can manage. Both lines must be capable of arresting and managing a failure of the other line.

Two Block—When a mechanical advantage system is fully collapsed and the pulleys are touching each other.

Tying Off Short—A safety technique where a person working on rope on an edge ties a knot close below and connects the loop to their harness creating an extra point of attachment.

Tyrolean—See High Line.

U

UIAA—The Union of International Alpine Associations. A European group that sets standards for mountaineering equipment.

Unified Command—In ICS, unified command is a unified team effort that allows all agencies with responsibility for the incident, either geographical or functional, to manage an incident by establishing a common set of incident objectives and strategies. This is accomplished without losing or abdicating agency authority, responsibility or accountability.

U-Rack—A type of Brake Bar Rack that has a U-shaped frame.

U-Rack
(shown without bars)

V

Vector—A force that has a magnitude and a direction.

Vector Pull—When a rope is tight between two points, a pull near the center of the rope in a perpendicular direction places a large force on each of the points. A vector pull can be used to lift a load a very short distance or to take the slack out of a back-tie anchor system.

Vertical—An evacuation that is essentially free hanging.

Victim Extrication Device—A device designed to be secured about the body of a victim in a harness like manner to provide support in a head—up or horizontal configuration for the purpose of lifting and transporting the victim with a life safety rope.

W

Webbing—Fabric woven in the form of a long strip.

Whistle Test—A theoretical analysis of a rope rescue system to determine what the system will do if all of the operators let go at the same time.

White Board Analysis—A determination of the force on each component based on the way it is used in the system.

Winch—A device for lifting or lowering a load with an integral cable or line and with gearing to provide a mechanical advantage when lifting or lowering.

Working End—The end of the rope that is used to tie the knot.

Working Load—The maximum load approved for a rope by the manufacturer. The working load is a percentage of the minimum breaking strength of the rope and varies depending on the type of construction (see Recommended Working Load).

Wristlets—Straps designed to be placed around the wrists or ankles of a person to allow lifting, lowering or dragging.

Z

Z-Rig—Another term for a 3:1 M/A system from the Z-shape the rope makes when the system is rigged.

Zero Margin—If the load that you are supporting is equal to the strength of your system, you have a zero margin of safety.

INDEX

Symbols

3D 50
3 sigma 24
540° Rescue Belay 58

A

Abrasion Resistance 32
Access 253, 327
Aerial Apparatus 302
A-Frame 307, 309
Alpine Butterfly 92
Anchor Plates 57, 104
Anchors 99, 332, 333
  backed-up 104
  change-of-direction 118
  contingency 117
  counterforce 118
  deviation 333
  high 299
  load-distributing 115, 116
  load-sharing 115
  pickets 107
  pretensioned 116
  strength 112
  systems 113
  terminology 100
  tests 385, 386, 387
ANSI 21
Antenna rescues 359
Arizona Vortex 273, 274, 301, 304
Ascenders 58
Ascending 237
  frog system 241
  Jumaring 240
  rope-walking 243
  tender system 239
  Texas system 240
ASSP 21
ASTM 17
AZTEK 67, 177, 193, 197, 246, 263, 264, 266, 270

B

Bags
  equipment 68
  rope 37
Bailout 363
Belay 9, 13, 149, 223
  automatic 224
  bottom 223
  CLUTCH 153
  devices 225
  independent 224
  MPD 154
  self 226
  tandem prusik 151, 224
Block Creel 30
Boots 78
Bowline 92
Braid on braid 30
Brake Bar Racks 49
Brake bars 49
Butterfly knot 92

C

Caged ladder rescues 359
Carabiner 42
CE 22
Choker 110
Clove hitch 86
CLUTCH 59
  ascending 238
  belaying 153, 250, 251
  lowering 159
  rappelling 231
  rigging 59
Cordage Institute 18
Cranes 302
Critical angle 100
Critical point analysis 200

D

Davit arms 302
Descenders 49
  Auto-locking 51
  rigging 59, 65, 161, 163, 231, 233
  tie off 66, 162, 164, 235
Descent control devices 49
Dog and Tails 192
Double CLUTCH TTRS 145
Double fisherman's bend 87
Double-Loop Figure 8 89

E

Edge protection 119
Elongation 33
Energy absorption 33
Enforcer 67
Equipment lists 377
Escape 363
  anchors 365
  lines 364
Escape Artist 367
Etriers 240

F

Fall arrest 247
Fall factor 248
Fall protection 245
Fear 11
Fibers 28
  aramid 29
  HMPE 29
  LCAP 29
  nylon 28
  polyester 28
  polypropylene 28
Figure 8 51, 88, 231
  bend 89
  descender 51, 231

  follow-through loop 89
  on a bight 88
  rappel 62, 218, 228
  tie off 235
Food/hydration 79

G

Gibbs 58
Gin poles 304
Girth hitch 110
Gloves 77
Guiding lines 283

H

Half hitches 86
Hand signals 324
Harness 73
  belt 73
  chest 74
  combo 74
  full-body 75
  hasty 95
  litter 139, 268
  sit 74
  victim 257
Haul team performance 173
Helmets 72
High directionals 299
High lines 291
High-strength tie-off 90
Hurley Picket Anchor System 109

I

Improvisation 5
Incident command system 320
Instructor 2

K

Kernmantle 29
Knot pass 56, 189
Knot pass pulley 56
Knots 81–98
  alpine butterfly 92
  bowline 92
  clove hitch 86
  double fisherman's bend 87
  double-loop Figure 8 89
  efficiency 82
  Figure 8 88
  Figure 8 bend 89
  Figure 8 follow-through loop 88
  Figure 8 on a bight 88
  high-strength tie-off 90
  mariner's knot 94
  mule tie-off 91
  Munter hitch 91
  overhand knot 85
  overhand loop 85
  passing 189
  poacher's knot 87
  Portuguese bowline 93
  Prusik hitch 86
  radium release hitch 95
  ring bend 85
  round turn & two half hitches 86
  tensionless hitch 90
  terminology 84
  trucker's hitch 94
  water knot 85

L

Ladder 311, 359
LAST 326
Lead climbing 249
Lighting 78
Litters 133
  harness 137
  insert 136
  loading 126
  rigging 137
  wheel 137
Litter shield 132, 137
Locate 326
Lowering systems 157

M

Manual 4
Mariner's knot 94
Mechanical advantage 167, 203
MPD 64
  belay 154
  lowering 160
  parking brake 66
  rigging 65
Mule tie-off 91
Munter hitch 91

N

NFPA 19
  test methods 25
NFPA 1983 19, 25

O

OSHA 17
Overhand knot 85
Overhand loop 85

P

Packaging 125
Patient loading 126
Patient protection 131
Patient tie-in 127
Petzl I'D 52
Pickets 107
Pick-off 264
Portuguese bowline 93
Preplan 320
Pretensioned back tie 101, 116
Pretensioned front tie 101
Progress capture device 169, 185
Prusik hitch 86
Pulleys 53
  knot pass 56
  prusik-minding 55
  self-tending 56
  swivel 56

R

Radium release hitch 95
Raising systems 167
Rappelling 217
Ratchet 169
Redundancy 9
Regulations 15
Risk analysis 8
Rope 27
  abrasion 32
  bag 37
  care 36
  color 34
  construction 29
  contamination 385, 386, 387
  diameter 32
  dynamic 33
  elongation 33
  escape 364
  fibers 28
  handling 34
  inspection 38
  log 37, 379
  low-stretch 28, 31, 33
  retire 38
  rules 39
  sheath 31
  static 33
  storage 37
  strength 30
  washing 38
Rope access 331
RPM 57

S

Safety 7
  check 10
  knife 79
  knots 83
Safety factor 207, 213
Safety line 225
Scaffold knot 87
School 2
Scissors 79
Screw links 48
Single-rope technique 10
Sizing up 13, 327
Skate block 287
Snow operations 373
Stabilization 13, 253, 328
Standards 15
Swivels 57
Systems
  1:1 175
  2:1 180
  3:1 176
  4:1 178, 180
  5:1 176, 177, 179
  6:1 179
  9:1 178
  analysis 199
  anchors 113
  belay 149
  complex 168
  dual capability two-tension 142
  knot pass 189
  lowering 157
  mechanical advantage 167, 172, 209
  piggyback 171
  powered 174
  raising 167
  ratchet 169
  reversing 183
  safety factor 200, 207
  simple 169
  twin-tension 141
  Z-rig 170, 181

T

Tactical rappel 228
Tender system 239
Tensionless hitch 90
Testing 23
T-method 203, 383
Touch system 10
Tower rescues 359
Travel restraint 246
Triaxial loading 42
Tripods 300
Trucker's hitch 94
Twin-tension systems 141

U

UIAA 22

V

Vector pull 266
Victim harness 257

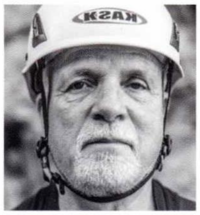
W

Water knot 85
Web
  flat 34
  needle loom 35
  sewn 35, 68
  shuttle loom 34
  tubular 35
Webbing 27
  daisy chain 97
Whistle commands 323
Whistle test 201
White board analysis 201

Z

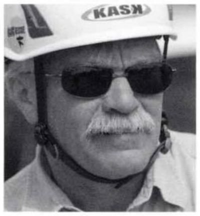
Z-system 170, 181

ABOUT THE CONTRIBUTORS



James A. Frank is the founder of CMC Rescue. Inc. He is involved in engineering, publications, and the education programs. As a team leader with Santa Barbara County Search & Rescue, he has over 45 years of experience with searches, technical rescue, and swiftwater rescues. Jim is a Technical Support member of the California Rescue Dog Association and a former backcountry ski patroller.

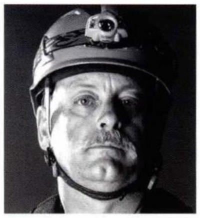
Now "retired", Jim served on the NFPA Technical Rescue Committee, the NFPA Technical Committee on Special Operations Clothing and Equipment, and ANSI/ASSE Z359 Committee on Fall Protection. One of the founding members of the Society for Rope Access Technicians, Jim chaired the Safe Practices committee during its first revision. He is also a member of ASTM F32 on Search & Rescue.



John McKently served as Director of the CMC School for many years. John started with CMC as an instructor in 1995 and full-time as the Director in 1996. John is also a long-time instructor for the Direction & Control of the Search Function, a California Office of Emergency Services search management course, including the winter operations session.

John has over 46 years of technical rescues and search operations with Montrose Search & Rescue, a Los Angeles County Sheriff's team. He is also a member of the specialized rescue unit for abandoned mines.

John has served on the board of directors for NASAR, and as a member of the FEMA standards committee. He has been a member of several ASTM and NFPA committees for many years.



Wayne Chapman started with CMC Rescue, Inc. as a part-time instructor in 1993 and in 2020 became the Director of the CMC School. Wayne was employed for over 30 years with the Orange County Fire Authority (OCFA) in Southern California serving in various capacities during his tenure with the OCFA including Firefighter, Paramedic, USAR Truck Firefighter, Heavy Rescue Captain, Truck Captain and Helicopter Crew Chief.

Wayne was also a member of FEMA's California Task Force 5 since its inception in 1993. He spent the majority of his time with the Task Force as the Section Coordinator for the Heavy Equipment and Rigging Specialists. During his time with CATF-5 he was an N.C.C.C.O certified Level I and II rigger and a recognized rigging subject matter expert with FEMA. He assisted with the development of California State Fire Training's Confined Space Rescue Technician and Rope Rescue Technician Programs. He was also a member of the California OES Regional Task Force Working Group, a non-voting member of the FEMA Rescue sub-group, and is a member of the ASTM Committee F-32 on Search & Rescue. Wayne also sits on the Board of Directors for ITRA. In 2018 Wayne retired from the Fire Service and joined CMC full-time as the Assistant School Director. Wayne teaches rope rescue, confined space rescue and other specialty rescue courses across the United States as well as internationally.

LeRoy Harbach began his rope rescue experience in the military and joined CMC as a part-time instructor in 1999. He was hired as a full-time instructor in 2008 following a 26-year career in the fire service with assignments including training officer and battalion chief. In 2009, CMC promoted LeRoy to Senior Instructor.

LeRoy has written several training programs for fire service and industrial technical rescue teams including rope rescue, confined space, trench rescue and structural collapse. He teaches open enrollment and contract classes for public agencies, government organizations and private industry across the United States and internationally.

Cedric Smith worked with CMC Rescue, Inc. from 2003 to 2020. Cedric was a member of CMC's engineering team, he was engaged in product development and facilitates certification of rescue equipment and specializes in equipment for air operations. Cedric represented CMC on ASTM F32 Committee on Search & Rescue and both the NFPA Technical Rescue Committee and NFPA Technical Committee on Special Operations Clothing and Equipment. He has been a frequent presenter at the International Technical Rescue Symposium (ITRS).

Cedric first joined search & rescue in Canada in 1995. He joined Santa Barbara Search & Rescue in mid-2003. He is an Incident Commander for the team, has held the Training Officer Position and now serves as the chair of the team's Incident Commander Committee.

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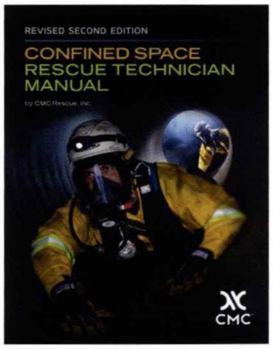
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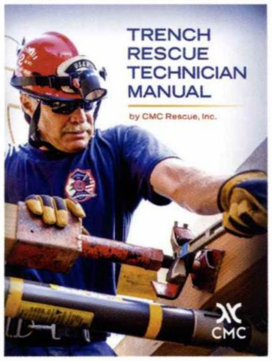
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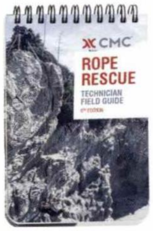
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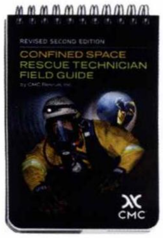
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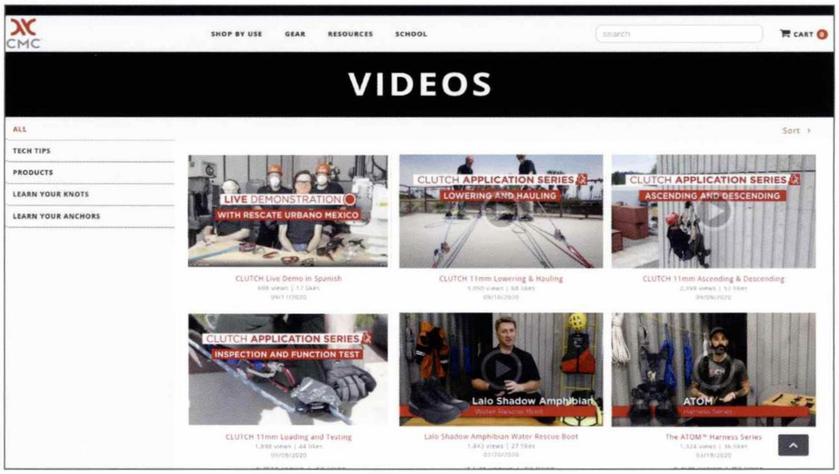
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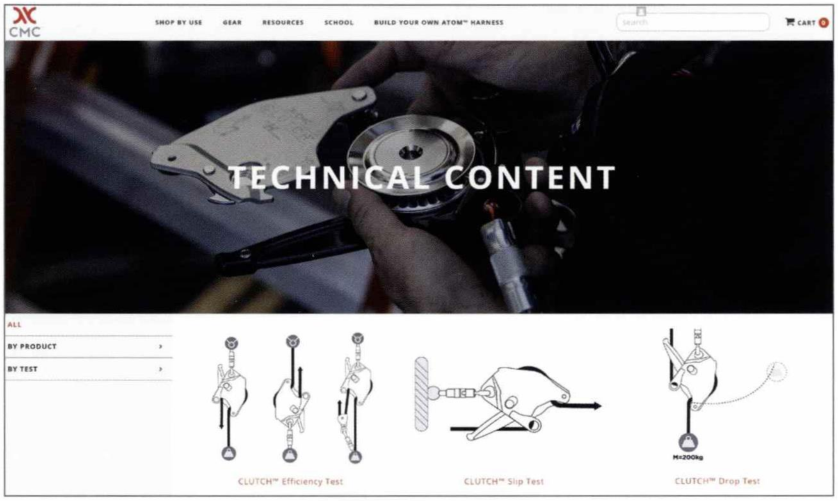
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Notes

ROPE RESCUE

TECHNICIAN MANUAL

6TH EDITION

The CMC Rope Rescue Technician Manual is the standard text for many fire departments, rescue teams and training programs across the country. The sixth edition reflects the latest advances in technology, equipment and procedures available to rescue professionals. Its concise style clearly sequences and describes the elements of rope rescue in a way that is both detailed and easy to understand. Well-drawn diagrams depict each recommended stage of rope rescue operations. The result is a very useful tool for rescue professionals at every skill level.

CMC has been an innovator in the emergency services industry for over 40 years. In 1978 Jim Frank endeavored to make rescue safer and more efficient by founding California Mountain Company (later CMC Rescue, now CMC), a company that sourced and supplied specialized life safety equipment to the rescue community.

Today, CMC is a globally recognized, employee-owned company that proudly manufactures many products in our ISO-certified Santa Barbara facility, and provides specialized education and training for rescue and rope access professionals.

CMC recommends that all rope technicians seek qualified, hands-on instruction from a trusted source. The CMC School provides this type of training with a focus on learning-by-doing. Open enrollment and custom courses are available worldwide. For more information on CMC or the CMC School, visit cmcpro.com.

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